CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

CENTRAL VALLEY ANADROMOUS FISH-HABITAT EVALUATIONS
October 1998 through September 1999

Annual Progress Report
Prepared for
U.S. Fish and Wildlife Service
Central Valley Anadromous Fish Restoration Program

Habitat Conservation Division
Stream Evaluation Program Technical Report No. 00-8
August 2000

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

CENTRAL VALLEY ANADROMOUS FISH-HABITAT EVALUATIONS
October 1998 through September 1999[1/,2/]

Annual Progress Report
Prepared for
U.S. Fish and Wildlife Service
Central Valley Anadromous Fish Restoration Program

August 2000

1/ Funded by the U.S. Fish and Wildlife Service pursuant to the CENTRAL VALLEY PROJECT IMPROVEMENT ACT to improve anadromous fish habitat in California's Central Valley streams.

2/ Stream Evaluation Program Technical Report No. 00-8 .

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Department of Fish and Game is conducting various investigations in Central Valley streams to acquire information on anadromous salmonid populations. Results of the investigations will be used to identify flow requirements for Central Valley anadromous salmonid populations. The work is being conducted pursuant to a cooperative agreement with the U.S. Fish and Wildlife Service to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The investigations have been ongoing since fall 1995 and have included the Sacramento, Yuba, American, Cosumnes, Calaveras, Stanislaus, Tuolumne, and Merced rivers. Data acquired on these streams varies from typing and mapping habitats using aerial photography to comprehensive evaluations and monitoring of spawner populations, spawning distribution, spawning habitat conditions, juvenile rearing, juvenile migration, and juvenile habitat conditions.
The comprehensive evaluations have been primarily focused on the reaches of the Sacramento and American rivers that are influenced by Central Valley Project operations.

To date, results of the investigations on the American River have provided for improved understanding of flow requirements of salmon and steelhead. The American River data are continually being used by water management and fishery management agencies to identify optimum allocation of flow required for conserving and restoring salmon and steelhead populations in the lower American River. These data along with data collected on the Sacramento River are also being used to globally identify status and needs of salmon and steelhead as they relate to basin-wide management of water and other habitat needs. The National Marine Fisheries Service (NMFS) has and continues to use data collected on winter-run chinook salmon and steelhead to identify conservation management actions on a real-time basis. Information collected on steelhead is some of the most recent available for the Central Valley and were used by the NMFS in their deliberation of listing steelhead as threatened in the Central Valley evolutionary significant unit (ESU). This information is presently being used to help identify critical habitat for steelhead in the Central Valley ESU, and in the deliberation of the listing of spring-run, fall-run and late-fall run chinook salmon in the Central Valley ESU.

Data collected to date on the American and Sacramento rivers are also being used to refine methods used to identify habitat needs, including flow, on these rivers as well as on other stream systems within the Central Valley. One of the primary objectives of these investigations is to develop and validate scientifically credible methods for determining habitat requirements for all life stages of salmon and steelhead that depend upon Central Valley streams.

During the period summarized in this report (October 1998 through September 1999), the majority of work was conducted in the Sacramento River. Spawner surveys were conducted on all four races of salmon: juvenile rearing and emigration monitoring was conducted on salmon and steelhead. Surveys were also conducted on the Cosumnes River fall-run chinook salmon population and habitat requirements.

INTRODUCTION

In July 1995, the California Department of Fish and Game(DFG) entered into an agreement with the U.S. Fish and Wildlife Service (FWS) to evaluate anadromous salmonid habitat requirements in Central Valley streams. Various studies have been developed and are being implemented by the Stream Evaluation Program to provide the FWS Central Valley Anadromous Fish Restoration Program with reliable scientific information. The information is to be used by DFG and FWS to develop flow recommendations to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The basic approach to the evaluations is outlined in *Proposal to define instream flow and habitat requirements for anadromous resources in Central Valley Streams, September 1994*. The approach includes developing a better understanding of the life history of chinook salmon and steelhead trout emphasizing the relationships between life stage requirements and manageable habitat attributes (e.g., flow, water temperature, channel conditions, etc.). Initially, the evaluations concentrated on the Sacramento and American rivers. Continued investigations will include individual evaluations of spawning, rearing, and migration on these and other Central Valley streams.

One of the requirements of the agreement is to provide the FWS with annual progress reports. This report covers the investigations conducted in the Sacramento River during the period October 1998 through the last week of September 1999. During that period, DFG conducted seven general investigations (Table 1).

Table 1. Investigations conducted by the Department of Fish and Game to determine anadromous salmonid habitat requirements in Central Valley streams - October 1998 through the last week of September 1999.

Investigation	Sacramento River	Cosumnes River
Habitat mapping	Completed	Initiated
Fall-run chinook salmon spawning	X	X
Late fall-run chinook salmon spawning	X	NA
Winter-run chinook salmon spawning	X	NA
Spring-run chinook salmon spawning	X	NA
Juvenile salmonid rearing	X	X
Juvenile salmonid emigration	X	X

The results of three investigations conducted on the upper Sacramento River during the reporting period are presented as Appendices III, IV, and V. These reports cover fall-run, late-fall run and winter-run chinook salmon spawning evaluations in the Sacramento River. Appendix VI covers the survey work conducted on the Cosumnes River.

UPPER SACRAMENTO RIVER REARING HABITAT EVALUATION

Rearing habitat investigations are intended to determine temporal and spatial distributions of the various juvenile life stages of anadromous salmonids in the upper Sacramento River. These investigations compliment juvenile emigration evaluations and should be conducted year around to fully understand behavior of juvenile salmonids relative to habitat conditions. Some of the information to be gained from our studies include: relative importance of upper river habitat to different life stages under varying conditions; temporal and physical significance of various habitat conditions; and significance of stream conditions downstream of the study area - basically an overall understanding of the relationship between fish and habitat in the upper river as it is influenced by potentially manageable biotic and abiotic habitat attributes.

Evaluation of anadromous salmonid rearing habitat in the upper Sacramento River was initiated in August 1996 using seine and snorkel surveys. The study area was located between river mile 271 (just downstream of Battle Creek) and river mile 302 (Keswick Dam) (Figure 1). Most sites sampled were located upstream of Battle Creek, hence upstream of the direct influence of Coleman National Fish Hatchery. Sample sites were selected from 143 habitat units located in the study area; these units had been previously mapped by the DFG (Appendix I). Habitat mapping was based on channel morphology using a stratified classification system similar to that used on the American River. Habitat types (e.g., pool, riffle, run, and glide) were stratified by habitat zone (flatwater, bar complex, side channel, and off channel). Our objective was to sample 3 replicates of 11 randomly selected habitats twice per month. For this report, all the data from habitats distinguished by zone (i.e. flatwater pool and bar complex pool) were combined to represent 5, instead of 11 habitats: riffle, pool, glide, run and off-channel. During the snorkel survey, two swimmers would survey a 150-ft long section randomly selected along each bank of the habitat unit. Data collected included: species, size in 25-mm size classes, and general habitat attributes (mean depth, mean velocity, cover, etc.). During the seining surveys, habitat units were sampled with a 50 x 4-ft beach seine. Up to two seine hauls were made per unit. Data collected included number of salmonids (by species); size of up to 50 salmon and trout, per haul, (i.e., fork length [FL] to the nearest 0.5 mm, and weight, to the nearest 0.1 g); and general habitat attributes of the site seined.

A total of 174 sites was sampled from 1 October 1998 (week 42) through 30 September 1999 (week 40). Survey sites included 60 riffles, 23 pools, 42 glides, 47 runs, and 2 off-channel sites (Table 2). Of the 143 units sampled, 61 were snorkeled and 23 were seined (Table 3).

Table 2. Weekly distribution of habitat types sampled during the upper Sacramento River rearing habitat evaluation study, October 1998–September 1999.

Week	Riffle	Pool	Glide	Run	Off-channel
No sampling weeks 40, 41, 44, 46 (1998) through 16 (1999), 19, and 23					
42(1998)	1	1	0	0	2
43(1998)	1	0	0	0	0
45(1998)	1	0	0	0	0
17(1999)	0	0	1	1	0
18	0	0	1	0	0
20	3	2	2	2	0
21	2	2	2	1	0
22	8	0	1	0	0
24	3	2	2	3	0
25	2	2	5	2	0
26	3	2	1	2	0
27	4	0	3	2	0
28	0	0	1	4	0
29	3	2	3	3	0
30	5	2	0	4	0
31	1	3	2	2	0
32	3	0	1	0	0
33	1	0	0	0	0
34	7	0	2	2	0
35	2	2	6	8	0
36	1	0	3	0	0
37	2	1	1	1	0
38	3	2	2	3	0
39	3	0	2	3	0
40(1999)	1	0	1	4	0
Total	60	23	42	47	2

Table 3. Distribution of habitat units (identification numbers per Appendix Table I) sampled by both seine and snorkel during the upper Sacramento River rearing habitat evaluation study, October 1998–September 1999.

Week	Seine only	Seine and snorkel	Snorkel
No sampling weeks 40, 41, 44, 46(1998) through 16(1999), 19, and 23			
42 (1998)	71, 72, 76, 80	-	-
43 (1998)	66	-	-
45 (1998)	61	-	-
17 (1999)	-	-	19, 18
18	-	-	43
20	-	-	12, 15, 36, 48, 63, 77, 81, 83, 97
21	10, 18	-	117, 118, 130, 136, 137
22	23	6, 22, 30	10, 18
24	-	123, 130	36, 54, 82, 91, 104, 110
25	-	-	6, 9, 12, 43, 44, 68, 81, 120, 129, 130, 140
26	-	-	6, 10, 101, 102, 103, 105, 110, 130,
27	-	-	18, 30, 38, 54, 55, 63, 75, 123, 110
28	-	104	81, 82, 91,
29	-	-	101, 103, 104, 106, 110, 118, 119, 120, 121, 122, 136
30	-	-	3, 13, 21, 22, 47, 52, 55, 58, 77, 84, 85
31	-	-	4, 15, 62, 85, 87, 90, 140, 142
32	-	123	84, 87
33	-	-	26

Table 3. (continued)

Week	Seine only	Seine and snorkel	Snorkel
34	10	6, 18, 21, 30, 31	-
35	-	38, 63, 75, 81, 82, 91, 104, 110, 130	-
36	-	-	110, 119, 120, 136,
37	-	-	13, 77, 84, 85, 90
38	-	-	3, 21, 22, 34, 47, 52, 67, 110, 123, 130
39	-	-	21, 30, 31, 38, 75, 81, 91, 104
40	-	-	55, 62, 85, 121, 122, 140

Snorkel Survey Results

Chinook Salmon

A total of 67,806 juvenile chinook salmon was counted during the snorkel survey (Table 4). The mean weekly number of salmon counted per sample site ranged from 0 (week 33) to 6,811 (week 29).

The majority of salmon counted were in the 26-50 mm FL range (48.1%) (Table 4; Figure 2). For the remaining size categories, >0.1% were <25 mm FL, 42.2% were in the 51-75 mm FL range, 9.2% in the 76-100 mm FL range, and 0.5% were >100 mm FL. Salmon in the 26-50 and 51-75 mm size ranges dominated the counts during most weeks (Figures 3-8).

Temporal salmon distribution varied both among and within habitat types (Table 5; Figures 9-14). The mean weekly salmon count was greatest for glides (2.24 fish/ft). Run counts averaged 1.65 fish/ft. Pools counts averaged 1.25 fish/ft followed by riffles which averaged 1.10 fish/ft. When fish were the most abundant (week 25), the number of fish/ft was greatest in glides, followed by runs, pools, and riffles.

Rainbow trout

A total of 9,746 rainbow trout was counted during the snorkel survey (Table 6). The mean weekly number of rainbow trout counted per sample site ranged from 0 (weeks 17, 21, and 22) to 538 (week 24).

Most trout observed were in the 26-50 mm FL range (44.5%) (Table 6; Figure 15). For the remaining size categories, 1.7% were <25 mm FL, 32.7% were in the 51-75 mm FL range, 19.5% were in the 76-100 mm FL range, and 1.6% were >100 mm FL. The greatest numbers of the larger fish (≥76 mm FL) were observed during weeks 24 and 25 (Figures 16-21); they were absent during weeks 17, 18, 20, 21, 22, 27, 30, 33, 34, 36, and 40. The greatest numbers of smaller fish (≤50 mm FL) were observed during weeks 24, 25, and 35; they were present every week sampled except weeks 17, 21, and 22.

Rainbow trout distribution over time varied among and within habitat types (Table 7; Figures 22-27). The overall mean numbers of fish/ft were 0.36 for riffles, 0.20 for glides, 0.19 for pools, and 0.13 for runs.

Table 4. Summary of chinook salmon data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1998–September 1999.

Week (beginning count)	Number of sites	Total count	No./site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
No sites sampled weeks 40(1998) through 16(1999), 19, and 23								
17 (18 Apr)	2	806	403.0	0	95.7	4.3	0	0
18 (25 Apr)	1	892	892.0	0	82.1	17.9	0	0
20 (9 May)	9	4,684	520.4	0.1	54.1	42.3	3.5	0
21 (16 May)	5	9,802	1,960.4	0	83.2	16.8	0	0
22 (23 May)	5	926	185.2	0	54.0	46.0	0	0
24 (6 Jun)	8	9,114	1,139.3	0	24.5	40.7	32.9	1.9
25 (13 Jun)	11	10,154	923.1	0	72.2	25.6	1.9	0.3
26 (20 Jun)	8	5,591	698.9	0	31.7	49.1	18.8	0.4
27 (27 Jun)	9	6,322	702.4	0	34.5	57.2	7.9	0.4
28 (4 Jul)	4	1,827	456.8	0	30.3	63.2	6.3	0.2
29 (11 Jul)	11	7,495	6,811.4	0	26.5	68.4	4.5	0.6
30 (18 Jul)	11	1,456	132.4	0	39.1	49.0	10.2	1.7
31 (25 Jul)	8	932	116.5	0	37.2	48.8	13.4	0.6
32 (1 Aug)	3	2,799	933.0	0	32.2	54.0	13.3	0.5
33 (8 Aug)	1	0	0	0	0	0	0	0
34 (15 Aug)	5	124	24.8	0	63.7	35.5	0.8	0
35 (22 Aug)	9	1,348	149.7	0	30.3	54.5	14.1	1.1

Table 4. (continued)

Week (beginning count)	Number of sites	Total count	No./site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
36 (20 Aug)	4	1,365	341.3	0	24.2	75.8	0	0
37 (5 Sep)	5	311	62.2	0	46.3	53.7	0	0
38 (12 Sep)	10	1,278	127.8	0.8	62.9	33.8	2.3	0.2
39 (19 Sep)	8	368	46.0	0	42.7	57.3	0	0
40 (26 Sep)	6	212	35.3	0	48.1	42.5	7.0	2.4
Total (mean)	143	67,806	474.2	(>0.1)	(48.1)	(42.2)	(9.2)	(0.5)

Table 5. Summary of total counts and counts per foot, by habitat type, of chinook salmon observed during snorkel surveys of rearing habitat in the upper Sacramento River, October 1998–September 1999.

	Riffle			Pool			Glide			Run		
Week	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft
No sites sampled weeks 40(1998) through 16(1999), 19 and 23												
17	0	-	-	0	-	-	1	595	1.98	1	211	0.70
18	0	-	-	0	-	-	1	892	2.97	0	-	-
20	3	2,652	2.95	2	597	0.99	2	505	0.84	2	930	1.55
21	1	700	2.33	2	825	1.38	1	7,702	25.67	1	575	1.92
22	4	726	0.61	0	-	-	1	200	0.67	0	-	-
24	2	287	0.48	1	1,900	6.33	2	2,762	4.60	3	4,165	4.63
25	1	206	0.69	1	210	0.70	6	6,725	3.74	3	3,013	3.35
26	4	2,475	2.06	2	1,526	2.54	1	500	1.67	1	1,090	3.63
27	4	2,856	2.38	0	-	-	3	691	0.77	2	2,775	4.62
28	0	-	-	0	-	-	1	85	0.28	3	1,742	1.93
29	3	585	0.65	2	1,190	1.98	3	2,340	2.60	3	3,380	5.63
30	5	624	0.42	2	120	0.20	0	-	-	4	712	0.59
31	1	65	0.22	3	160	0.18	2	320	0.53	2	387	0.65
32	2	2,794	4.66	0	-	-	1	5	0.02	0	0	-
33	1	-	-	0	-	-	0	-	-	0	0	-
34	3	102	0.11	0	-	-	1	18	0.06	1	4	0.01
35	1	8	0.03	1	85	0.28	3	335	0.56	4	920	0.76

Table 5. (continued)

Week	Riffle			Pool			Glide			Run		
	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft
36	1	535	1.78	0	-	-	3	830	0.92	0	-	-
37	2	195	0.33	1	2	0.01	1	70	0.23	1	44	0.15
38	3	75	0.08	2	505	0.84	2	604	1.01	3	94	0.10
39	3	31	0.05	0	-	-	2	241	0.40	3	96	0.11
40	1	0	-	0	-	-	1	80	0.27	4	132	0.11
Total (mean)	45	14,916	(1.10)	19	7,120	(1.25)	38	25,500	(2.24)	41	20,270	(1.65)

Table 6. Summary of rainbow trout data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1998–September 1999.

Week (beginning count)	Number of sites	Total count	No./site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
No sites sampled weeks 40(1998) through 16(1999), 19, and 23								
17 (Apr 18)	2	0	0	0	0	0	0	0
18 (Apr 25)	1	3	3.0	100	0	0	0	0
20 (May 9)	9	1	0.1	0	100	0	0	0
21 (May 16)	5	0	0	0	0	0	0	0
22 (May 23)	5	0	0	0	0	0	0	0
24 (June 6)	8	4,303	537.9	0	46.5	20.9	30.6	2.0
25 (June 13)	11	1,697	154.3	0	31.4	46.4	19.2	3.1
26 (June 20)	8	164	20.5	14.6	70.1	9.1	0.6	5.5
27 (June 27)	9	644	71.5	0	62.9	34.8	2.3	0
28 (July 4)	4	243	60.8	0	85.2	14.0	0	0.8
29 (July 11)	11	217	19.7	4.6	90.0	4.6	0.4	0.4
30 (July 18)	11	151	13.7	8.6	66.9	24.5	0	0
31 (July 25)	8	507	63.4	12.8	51.1	31.0	4.9	0.2
32 (Aug 1)	3	312	104.0	2.6	16.3	65.7	14.4	1.0
33 (Aug 8)	1	6	6.0	0	100	0	0	0
34 (Aug 15)	5	4	0.8	0	100	0	0	0
35 (Aug 22)	9	1,202	133.5	3.9	32.2	50.5	13.3	.1

Table 6. (continued)

Week (beginning count)	Number of sites	Total count	No./site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
36 (Aug 29)	4	25	6.2	0	52.0	48.0	0	0
37 (Sept 5)	5	29	5.8	0	6.9	65.5	27.6	0
38 (Sept 12)	10	158	15.8	0	7.6	88.6	2.5	1.3
39 (Sept 19)	8	53	6.6	0	35.8	62.3	0	1.8
40 (Sept 26)	6	27	4.5	0	85.2	14.8	0	0
Total (mean)	143	9,746	(68.2)	(1.7)	(44.5)	(32.7)	(19.5)	(1.6)

Table 7. Summary of total counts and counts per foot, by habitat type, of rainbow trout observed during snorkel surveys of rearing habitat in the upper Sacramento River, October 1998–September 1999.

	Riffle			Pool			Glide			Run		
Week	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft
No sites sampled weeks 40(1998) through 16(1999), 19 and 23												
17	0	0	0	0	0	0	1	0	0	1	0	0
18	0	0	0	0	0	0	1	3	0.01	0	0	0
20	3	0	0	2	1	<0.01	2	0	0	2	0	0
21	1	0	-	2	0	-	1	0	0	1	0	0
22	4	0	0	0	0	-	1	0	0	0	0	0
24	2	4,076	6.79	1	215	0.72	2	0	0	3	12	0.01
25	1	0	-	1	6	0.02	6	1,654	0.92	3	37	0.04
26	4	14	0.12	2	130	0.22	1	0	0	1	20	0.06
27	4	44	0.37	0	0	-	3	315	0.35	2	285	0.48
28	0	0	-	0	0	-	1	71	0.24	3	172	0.19
29	3	25	0.28	2	62	0.10	3	120	0.13	3	10	0.01
30	5	134	0.09	2	4	0.01	0	-	-	4	13	0.01
31	1	0	0	3	486	0.54	2	6	0.01	2	15	0.03
32	2	273	0.46	0	0	-	1	39	0.13	0	0	-
33	1	6	0.02	0	0	-	0	-	-	0	0	-
34	3	2	<0.01	0	0	-	1	0	-	1	2	0.01

Table 7. (continued)

Week	Riffle			Pool			Glide			Run		
	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft	No. sites	Count	No./ft
35	1	16	0.05	1	175	0.58	3	41	0.05	4	970	0.81
36	1	19	1.85	0	0	-	3	6	0.01	0	0	-
37	2	18	0.36	1	1	0.01	1	1	<0.01	1	9	0.03
38	3	148	0.23	2	7	0.03	2	0	0	3	3	<0.01
39	3	14	0.05	0	0	-	2	11	0.02	3	28	0.03
40	1	14	0.05	0	0	-	1	0	0	4	13	0.01
Total (mean)	45	4,803	(0.36)	19	1,087	(0.19)	38	2,267	(0.20)	41	1,589	(0.13)

Seine Survey Results

Chinook salmon

A total of 2,059 salmon was collected from 31 sites by seine (Table 8). The weekly mean size of salmon ranged from 38.0 mm FL (week 32) to 63.3 mm FL (week 45). Emergent-sized fish (<45 mm FL) were observed during every week sampled. Smolt-sized fish (≥70 mm FL) were observed during every week sampled but week 32.

Habitat types were not equally represented in the overall sampling effort. Catch per habitat unit were as follows: 14 riffles yielded a mean catch 64.8 fish/site, 3 pools yielded of 211.0 fish/site, 5 glides yielded 23.4 fish/site, and 7 runs yielded 41.9 fish/site (Table 8).

The size distribution of seine-caught fish are presented in Figures 28-31. The size ranges of seine-caught fish were generally less than the size ranges of fish observed during the snorkel surveys. More larger salmon were observed during the snorkel surveys than were captured in seines during 5 of the 7 weeks when both surveys were conducted (weeks 24, 28, 32, 34, and 35). Seine avoidance by larger fish or the inability to sample comparable sites likely influenced this result.

Rainbow trout

A total of 222 rainbow trout was collected from 31 sites (Table 9). The mean weekly mean size ranged from 29.9 mm FL (week 34) to 65.1 mm FL (week 45). Recently emerged fish (<35 mm FL) were collected during weeks 42, 45 of 1998, 24, 28, 32, 34, and 35 of 1999. Larger smolt-sized fish (≥100 mm FL) were caught during weeks 43 and 45.

Catches per habitat unit were as follows: 14 riffles yielded a mean catch of 11.0 fish per site, 3 pools yielded 4.0 fish per site, 5 glides yielded 1.2 fish per site, and 7 runs yielded 4.9 fish per site (Table 9).

The size distributions of seine caught fish are presented in Figures 32-34. Similar to the results for salmon, the size ranges of seine-caught trout was less than the size ranges of trout observed during the snorkel surveys during 5 of the 7 weeks when both seines and snorkel surveys were conducted (weeks 24, 28, 32, 34, and 35). More larger trout (>100 mm FL) were observed during the snorkel surveys than were captured in seines.

Table 8. Weekly catch statistics by habitat type for chinook salmon caught by beach seine in the upper Sacramento River, October 1998- September 1999.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)
No sites sampled weeks 40, 41, 44, 46 (1998)-20 (1999), 23, 25, 26, 27, 29, 30, 31, 33, and 36-40															
42 (Oct 11)	1	1	64.0	1	0	-		no sites sampled			no sites sampled		4*	110*	57.5(45-86)
43 (Oct 18)	1	158	53.4 (38-87)		no sites sampled			no sites sampled			no sites sampled		1	158	53.4 (38-87)
45 (Nov 1)	1	46	63.3 (38-94)		no sites sampled			no sites sampled			no sites sampled		1	46	63.3 (38-94)
21 (May 16)	1	0	-		no sites sampled		1	26	49.9 (37-70)		no sites sampled		2	26	49.9 (37-70)
22 (May 23)	3	388	44.0 (30-73)		no sites sampled			no sites sampled		1	1	53.0	4	389	44.0 (30-73)
24 (Jun 6)	1	246	42.8 (35-84)	1	631	42.8 (35-84)		no sites sampled			no sites sampled		2	877	42.8 (35-84)
28 (Jul 4)		no sites sampled			no sites sampled			no sites sampled		1	179	46.8 (33-77)	1	179	46.8 (33-77)
32 (Aug 1)	1	1	38		no sites sampled			no sites sampled			no sites sampled		1	1	38.0
34 (Aug 15)	4	67	50.7 (32-81)		no sites sampled		1	20	47.7 (34-68)	1	0	-	6	87	50.7 (32-81)
35 (Aug 22)	1	0	-	1	2	53.7 (34-82)	3	71	60.3 (36-82)	4	113	49.7 (34-76)	9	186	53.7 (34-82)
Totals (mean)	14	907	47.4 (30-94)	3	633	42.9 (34-84)	5	117	57.5 (34-82)	7	293	47.9 (33-77)	31	*2,059	48.6 (30-94)

* Two off-channel sites yielded 109 chinook salmon with an average FL of 57.6 and a range of 45-86 mm. These values are included in the totals.

Table 9. Weekly catch statistics by habitat type for rainbow trout collected by seine on the upper Sacramento River, October 1998–September 1999.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)	No. sites	count	FL mean (range)
No sites sampled weeks 40, 41, 44, 46 (1998)-20 (1999), 23, 25, 26, 27, 29, 30, 31, 33, and 36-40															
42 (Oct 11)	1	4	49.0 (33-68)	1	0	-		no sites sampled			no sites sampled		4*	20*	49.0 (33-68)
43 (Oct 18)	1	46	63.9 (42-134)		no sites sampled			no sites sampled			no sites sampled		1	46	63.9 (42-134)
45 (Nov 1)	1	68	65.1 (31-148)		no sites sampled			no sites sampled			no sites sampled		1	68	65.1 (31-148)
21 (May 16)	1	0	-		no sites sampled		1	0	-		no sites sampled		2	0	-
22 (May 23)	3	0	-		no sites sampled			no sites sampled		1	0	-	4	0	-
24 (Jun 6)	1	3	32.7 (27-41)	1	6	37.0 (27-41)		no sites sampled			no sites sampled		2	9	35.6 (27-49)
28 (Jul 4)		no sites sampled			no sites sampled			no sites sampled		1	17	47.4 (28-85)	1	17	47.7 (28-85)
32 (Aug 1)	1	10	32.1(22-42)		no sites sampled			no sites sampled			no sites sampled		1	10	32.1 (22-42)
34 (Aug 15)	4	23	29.9 (23-44)		no sites sampled		1	0	-	1	0	-	6	23	29.9 (23-44)
35 (Aug 22)	1	0	-	1	6	31.0 (25-37)	3	76	49.5 (41-58)	4	17	37.6 (24-58)	9	29	37.6 (24-58)
Totals (mean)	14	154	55.1 (22-148)	3	12	34.0 (25-41)	5	6	49.5 (41-58)	7	34	44.4 (24-85)	31	222	52.4 (22-148)

* Two of-channel sites yielded 15 steelhead with an average FL of 52.4 mm and a range of 45-62 mm. These values are included in the totals.

UPPER SACRAMENTO RIVER EMIGRATION SURVEY

Emigrating juvenile salmonids were monitored using a rotary screw trap (RST) located upstream of the Balls Ferry Bridge (RM 278). The purpose of the monitoring is to determine the timing and relative abundance of salmon and rainbow trout (potentially steelhead) emigration relative to precedent conditions of spawning and rearing in the upper natal stream reach. The results presented cover the period from 1 October 1998 (week 40) through 30 September 1999 (week 40).

Sampling was conducted for most of the year, however, RST sampling effort was reduced during several weeks in October and November 1998 and September of 1999 to about 1/10th the normal sampling effort to avoid exceeding our Section 10 take limit for winter-run chinook salmon. Sampling was conducted throughout most of the remainder of the year except for occasional short periods when the traps had to be repaired.

Data acquired from the RSTs included number of hours fished and juvenile salmonids collected by species. Race for chinook salmon was determined using the length-at-time criteria developed by Frank Fisher (DFG - Red Bluff). All salmon identified as winter run, spring run, and late-fall run were measured and weighed (FL in mm and weight in g). In addition, up to 300 fall-run-sized salmon were randomly selected per trap up to twice daily, then measured and weighed. All juvenile rainbow trout were counted and measured.

Trap efficiency was evaluated by marking a portion of salmon captured (except winter run). Fish were marked with dyes either by injecting them with Alcian blue or, rarely, by bathing them in Bismark Brown *Y* stain. Fish captured and marked at Balls Ferry were transported upstream about 2,500 feet then released. All salmon captured were checked for marks as they were counted. Efficiency was determined weekly by calculating the percentage of marked fish recaptured.

Emigration Results

Chinook Salmon

Juvenile salmon were collected every week sampled (Table 10; Figure 35). Catch rates ranged from 0.46 fish/h (week 49) to 70.34 fish/h (week 3). The highest catches were made during from late December 1998 through early February 1999 (weeks 1–6) (Figure 36). Mean weekly size ranged from 35.8 mm FL (week 50) to 83.3 mm FL (week 38). Recently emerged-sized fish (< 50 mm FL) were captured every week. Larger smolt-sized fish (≥ 70 mm FL) were collected every week except weeks 40 and 50 (1998), and weeks 7 through 11 of 1999 (Appendix II - Figures 1-14).

A total of 85,166 chinook salmon was collected by RST including 1,100 spring-run sized salmon; 66,101 fall-run sized salmon, 10,585 late-fall-run sized salmon, and 7,380 winter-run sized salmon

(2,201 were from brood year [BY] 1998 and 5,179 were BY 1999). Spring run catch peaked in weeks 51–2 (Figure 37). Fall run emigration peaked during weeks 2 and 3. Late-fall salmon catch peaked during weeks 18–21. Winter-run (BY 1998) emigration had already started when the reporting period began on 1 October 1998. BY 1999 winter run emigration began to substantially increase in week 38 when trapping effort was reduced to accommodate our Section 10 permit conditions.

The weekly mean size ranged from 30 to 125 mm FL for spring-run salmon (Figure 38), from 29 to 140 mm FL for fall run, from 29 to 147 mm FL for late-fall run, and from 27 to 165 mm FL for winter run.

Trapping efficiency, as measured by the recovery of dye-marked fish, ranged from 0.00% (weeks 52 and 8) to 1.42% (week 34) with a yearly mean of 0.70% (Table 11).

Rainbow Trout

A total of 674 rainbow trout was captured. No steelhead were collected during weeks 45, 47, 48, 49 in November, week 51 in December, week 6 in January, week 8 in February, and week 11 in March and week 16 in April (Table 12; Figure 39). Weekly catches ranged from 0 (9 weeks described above) to 74 (week 33). Weekly catch rates (catch/h) ranged from 0.00 fish/h to 0.54 fish/h (week 40 of 1999) (Figure 40). Mean weekly size ranged from 28.0 mm FL (week 9) to 650.0 mm FL (week 7). Individual fish size ranged from 15 to 750 mm FL.

Table 10. Summary of catch statistics for chinook salmon collected by rotary screw trap at Balls Ferry (RM 278) during the upper Sacramento River emigration survey, October 1998–September 1999.

Week	Start date	Weekly catch	Catch/hr	Size statistics			
				Mean	Minimum	Maximum	SD
40(1998)	Oct 1	321	13.52	36.6	33	53	1.81
41	Oct 4	1,210	24.82	37.0	33	97	4.68
42	Oct 11	271	12.90	37.7	34	87	7.8
43	Oct 18	100	3.77	40.1	33	132	14.34
44	Oct 25	13	0.96	44.4	32	81	14.36
45	Nov 1	46	1.28	56.7	33	107	15.68
46	Nov 8	198	4.13	58.1	33	113	14.11
47	Nov 15	58	1.26	65.7	34	123	22.91
48	Nov 22	17	0.58	44.8	30	81	15.59
49	Nov 29	34	0.46	46.5	34	98	13.85
50	Dec 6	38	1.49	35.8	32	40	1.83
51	Dec 13	433	8.79	37.7	32	118	8.55
52	Dec 20	590	26.52	49.5	34	125	24.31
1	Dec 27	4,090	70.21	41.4	34	126	15.57
2	Jan 3	8,402	60.66	41.4	31	127	16.52
3	Jan 10	10,463	70.34	37.6	31	118	4.47
4	Jan 17	3,582	35.18	37.9	34	108	4.17
5	Jan 24	3,226	24.21	38.3	29	111	4.38
6	Jan 31	4,887	37.38	39.1	35	147	7.64
7	Feb 7	204	7.70	38.7	35	61	2.46
8	Feb 14	204	4.14	38.4	34	44	1.41
9	Feb 21	1,052	8.97	39.0	33	56	1.93
10	Feb 28	731	5.57	38.2	34	49	1.61
11	Mar 7	797	5.34	39.2	34	58	1.99
12	Mar 14	1,840	11.41	39.8	30	77	3.77
13	Mar 21	3,391	22.16	40.0	31	153	6.74
14	Mar 28	3,221	20.75	42.3	34	165	10.39
15	Apr 4	2,706	16.33	41.4	35	132	7.68
16	Apr 11	2,869	17.15	41.4	32	122	9.55

Table 10. (continued)

Week	Start date	Weekly catch	Catch/hr	Size statistics			
				Mean	Minimum	Maximum	SD
17	Apr 18	2,078	12.44	45.6	31	163	13.80
18	Apr 25	2,107	12.65	51.4	32	125	16.58
19	May 2	1,626	10.19	51.1	33	115	16.04
20	May 9	2,463	14.64	51.9	34	96	15.15
21	May 16	2,526	16.98	56.3	34	99	16.65
22	May 23	1,182	13.13	59.8	29	103	16.22
23	May 30	870	6.95	67.1	35	110	16.66
24	Jun 6	1,349	9.34	66.5	30	109	16.62
25	Jun 13	1,511	9.44	64.0	31	110	18.56
26	Jun 20	1,107	6.64	67.2	32	112	18.93
27	Jun 27	1,076	6.61	69.3	32	105	18.63
28	Jul 4	756	8.74	64.2	33	99	18.64
29	Jul 11	1,004	6.06	62.5	33	100	19.27
30	Jul 18	949	5.73	65.5	34	117	18.48
31	Jul 25	935	5.57	69.0	33	106	15.15
32	Aug 1	830	4.93	68.7	30	140	17.19
33	Aug 8	1,210	7.20	62.1	30	114	19.60
34	Aug 15	1,186	6.94	61.4	29	108	19.61
35	Aug 22	953	5.67	64.2	31	125	23.14
36	Aug 29	832	9.90	58.2	30	122	23.79
37	Sept 5	600	22.86	76.4	33	118	21.46
38	Sept 12	1,658	35.66	83.3	34	131	14.07
39	Sept 19	627	26.68	80.1	34	127	21.43
40(1999)	Sept 26	737	30.71	75.1	34	122	23.94
Total		85,166	15.35	51.18	29	165	19.00

Week	Number marked	Number recaptured	Efficiency (%)
40-51	0	-	-

Table 11. Summary of capture efficiency test results for chinook salmon collected by rotary screw trap at Balls Ferry during the upper Sacramento River emigration survey, 2 October, 1998–22 September, 1999.

Week	Number marked	Number recaptured	Efficiency (%)
52	470	0	0
1	1,655	18	1.09
2	5,011	68	1.36
3	6,017	36	0.59
4	350	4	1.14
5	3,013	11	0.36
6	4,425	26	0.59
7	0	-	-
8	124	0	0
9	925	7	0.76
10	643	5	0.78
11	681	2	0.29
12	1,624	11	0.68
13	3,034	22	0.73
14	2,951	13	0.44
15	2,506	13	0.52
16	2,451	11	0.45
17	1,675	12	0.72
18	1,811	14	0.77
19	1,348	17	1.26
20	2,039	21	1.03
21	2,167	10	0.46
22	873	8	0.92
23	704	4	0.57

Table 11 (continued).

Week	Number marked	Number recaptured	Efficiency (%)
24	1,197	7	0.58
25	1,165	6	0.52
26	1,009	1	0.09
27	904	2	0.22
28	362	2	0.55
29	701	5	0.71
30	762	3	0.39
31	773	5	0.65
32	665	3	0.45
33	723	10	1.38
34	703	10	1.42
35	538	3	0.56
36	321	4	1.25
37	0	-	-
38	0	-	-
39	0	-	-
Total	56,320	394	0.70

Table 12. Summary of catch statistics for rainbow trout collected by rotary screw trap at Balls Ferry (RM 278) during the upper Sacramento River emigration survey, October 1998–September 1999.

Week	Start date	Weekly catch	Catch/hr	Size statistics			
				Mean	Minimum	Maximum	SD
40(1998)	Oct 1	5	0.21	62.8	41	110	24.8
41	Oct 4	3	0.06	59.3	52	72	8.9
42	Oct 11	4	0.19	57.0	36	68	13.7
43	Oct 18	3	0.11	131.7	51	180	57.4
44	Oct 25	1	0.07	100.0	100	100	-
45	Nov 1	0	-	-	-	-	-
46	Nov 8	5	0.10	148.8	47	390	124.8
47	Nov 15	0	-	-	-	-	-
48	Nov 22	0	-	-	-	-	-
49	Nov 29	0	-	-	-	-	-
50	Dec 6	1	0.04	155.0	155	155	-
51	Dec 13	0	-	-	-	-	-
52	Dec 20	3	0.13	83.0	75	95	8.6
1	Dec 27	2	0.03	73.5	71	76	2.5
2	Jan 3	3	0.02	209.3	88	380	124.2
3	Jan 10	4	0.03	482.5	160	750	229.6
4	Jan 17	3	0.03	256.7	70	500	180.1
5	Jan 24	1	0.01	67.0	67	67	-
6	Jan 31	0	-	-	-	-	-
7	Feb 7	1	0.04	650.0	650	650	-
8	Feb 14	0	-	-	-	-	-
9	Feb 21	1	0.01	28.0	28	28	-
10	Feb 28	1	0.01	79.0	79	79	-
11	Mar 7	0	-	-	-	-	-
12	Mar 14	1	0.01	54.0	54	54	-
13	Mar 21	1	0.01	280.0	280	280	-
14	Mar 28	3	0.02	87.0	71	95	11.3

Table 12. (continued)

Week	Start date	Weekly catch	Catch/hr	Size statistics			
				Mean	Minimum	Maximum	SD
15	Apr 4	3	0.02	149.3	58	310	113.9
16	Apr 11	0	-	-	-	-	-
17	Apr 18	17	0.10	69.5	51	200	34.2
18	Apr 25	59	0.35	62.0	40	84	9.4
19	May 2	32	0.20	56.5	37	74	7.6
20	May 9	65	0.39	56.6	28	210	23.8
21	May 16	40	0.27	68.2	37	450	61.9
22	May 23	17	0.19	54.6	26	71	10.6
23	May 30	9	0.07	55.9	34	62	8.0
24	Jun 6	7	0.05	108.0	50	410	123.4
25	Jun 13	15	0.09	48.9	27	80	17.7
26	Jun 20	28	0.17	41.0	21	93	18.8
27	Jun 27	31	0.19	39.5	24	87	18.6
28	Jul 4	12	0.14	35.1	25	60	11.6
29	Jul 11	30	0.18	48.9	21	112	26.9
30	Jul 18	18	0.11	56.4	23	117	28.2
31	Jul 25	14	0.08	53.9	25	97	19.8
32	Aug 1	24	0.14	48.8	28	98	15.6
33	Aug 8	74	0.44	49.0	15	114	16.2
34	Aug 15	45	0.26	54.8	22	106	16.8
35	Aug 22	22	0.13	57.7	41	86	12.1
36	Aug 29	31	0.37	57.3	41	99	15.4
37	Sept 5	5	0.19	62.0	55	68	5.2
38	Sept 12	12	0.26	62.8	48	92	14.2
39	Sept 19	5	0.21	90.0	65	140	29.6
40(1999)	Sept 26	13	0.54	67.2	48	82	11.3
Total		674	0.12	62.2	15	750	28.5

FIGURES

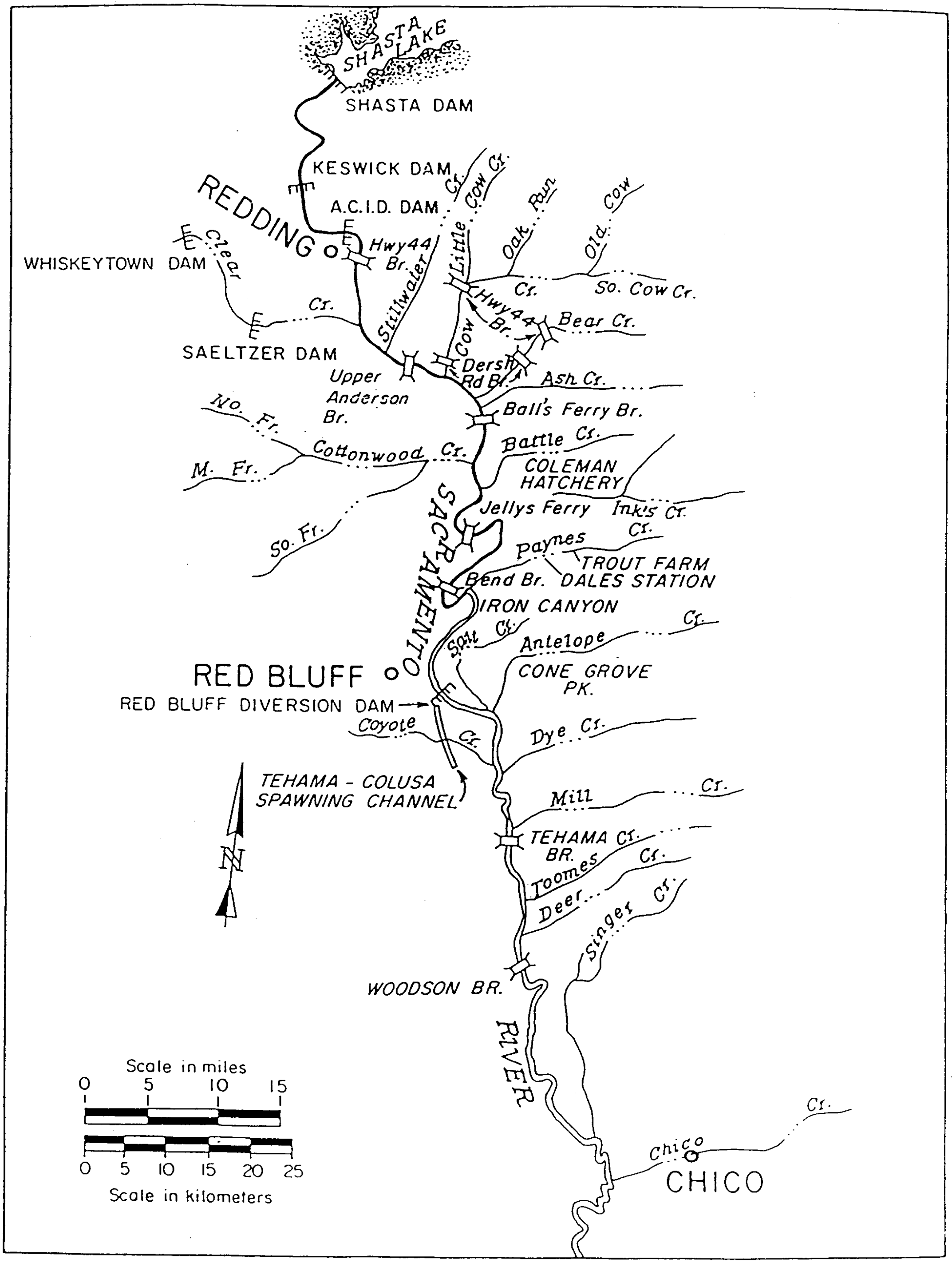


Figure 1. Upper Sacramento River.

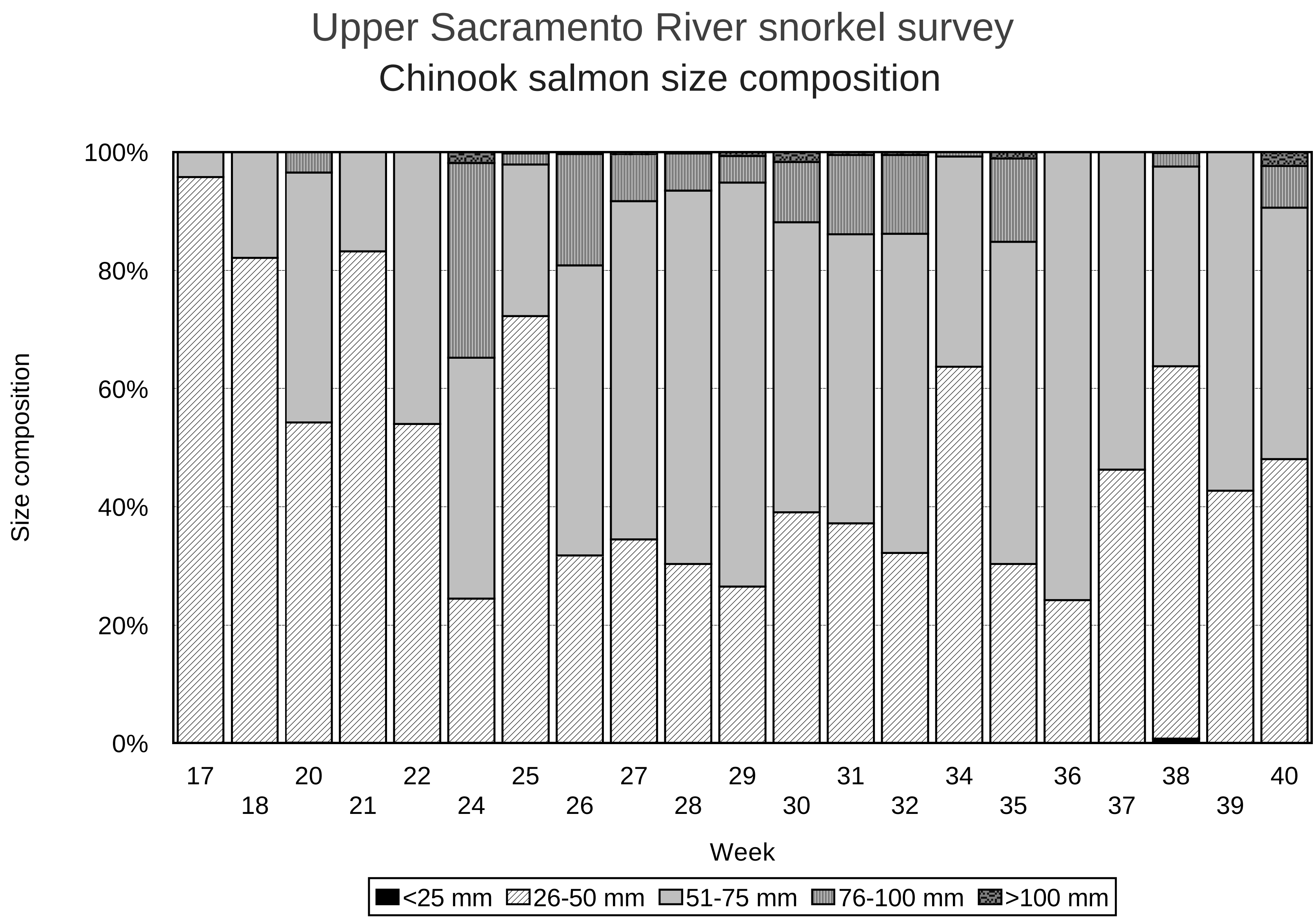


Figure 2. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, October 1998 - September 1999. No sites were sampled Week 41 through Week 16, as well as weeks 19,23, 33.

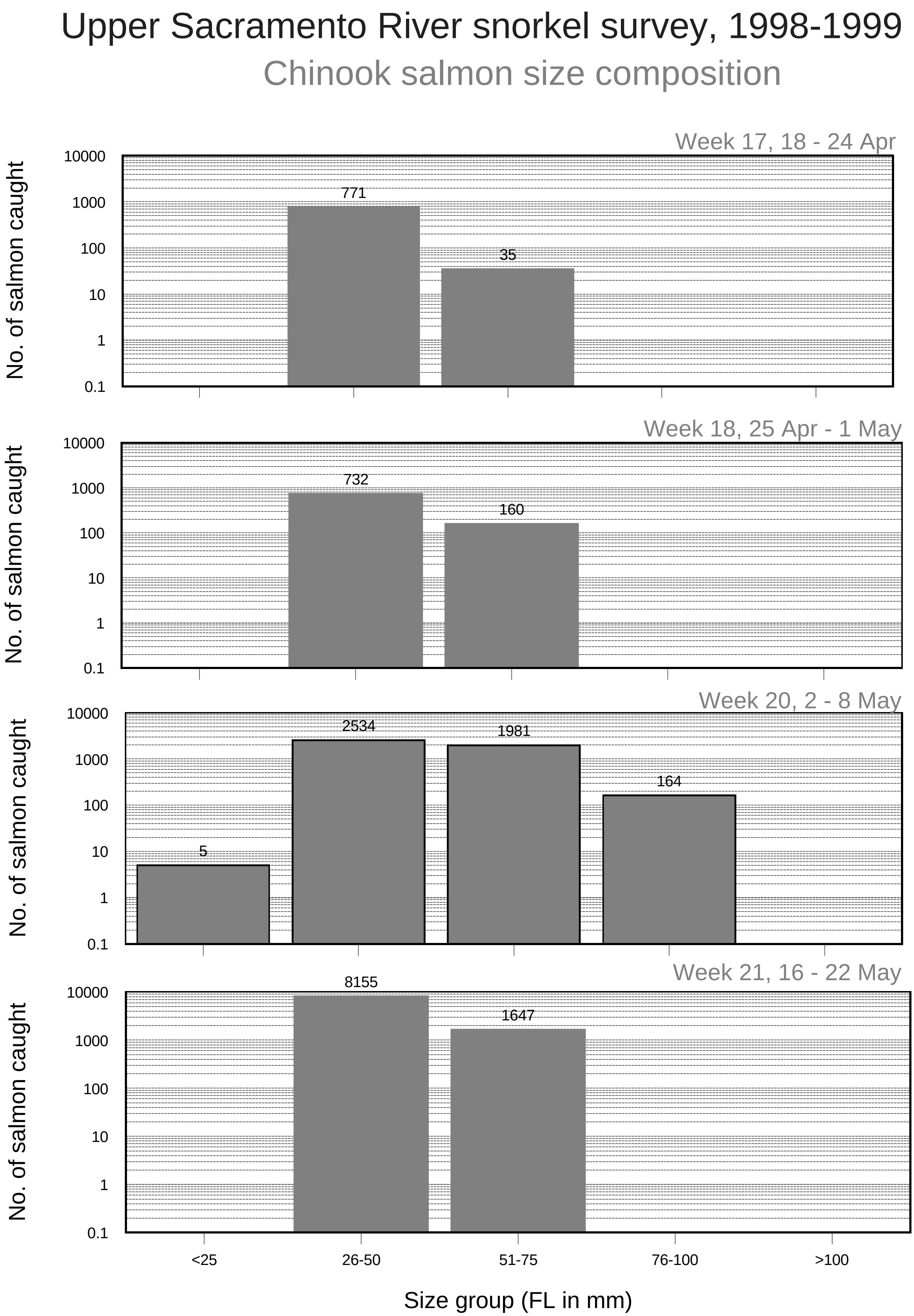


Figure 3. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 18 April - 22 May 1999.

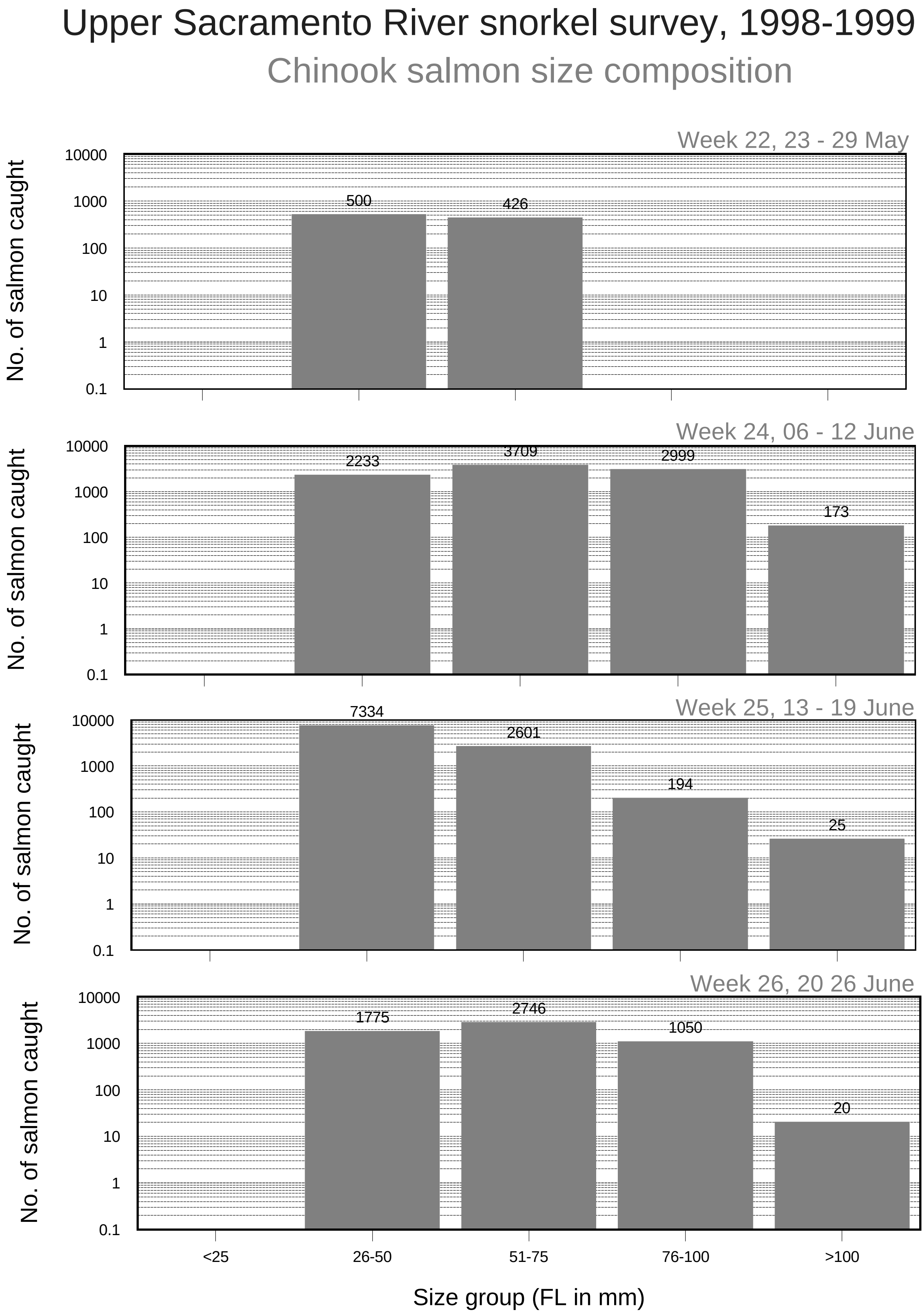


Figure 4. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 23 May - 26 June, 1999.

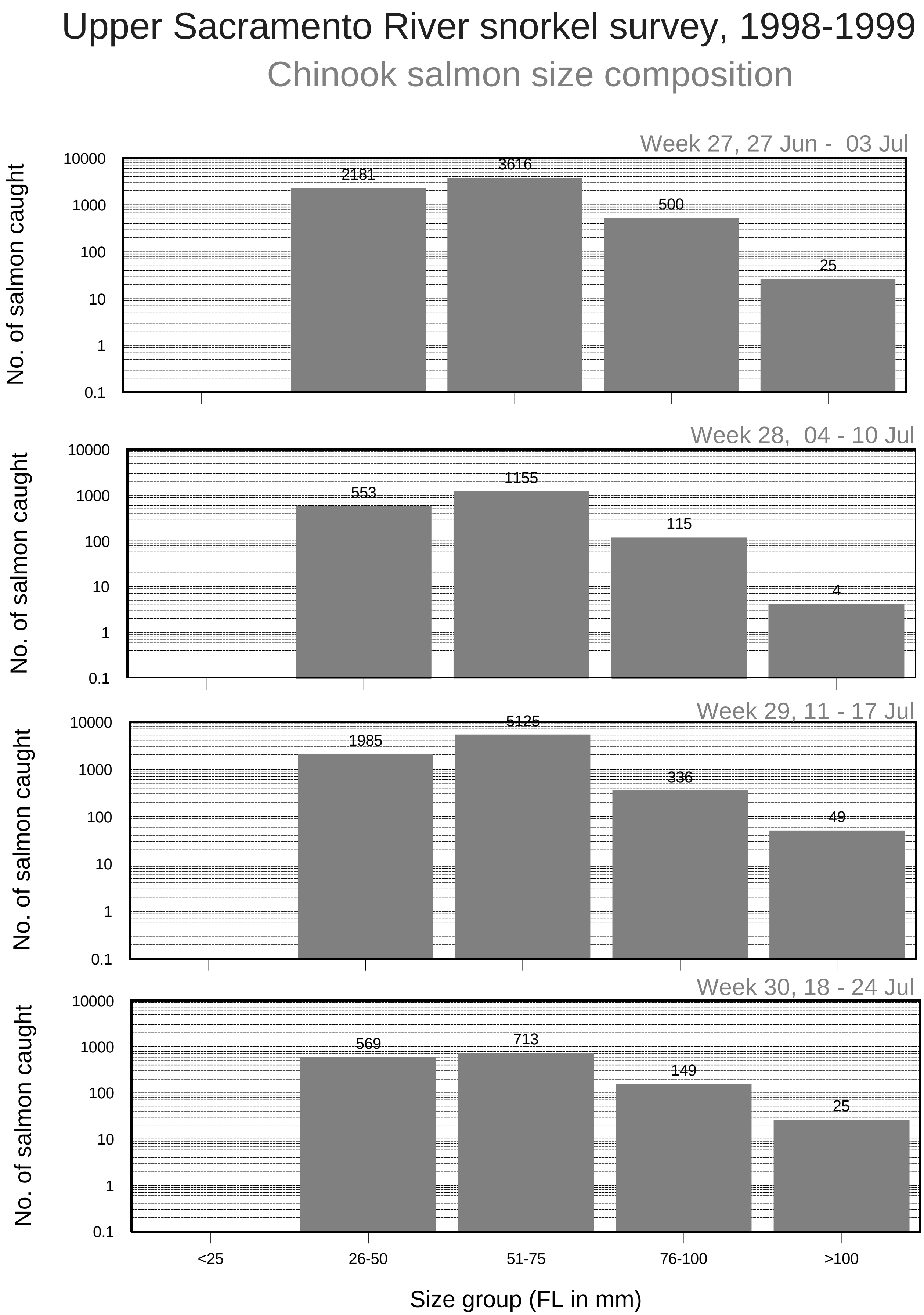


Figure 5. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 27 June - 24 July, 1999.

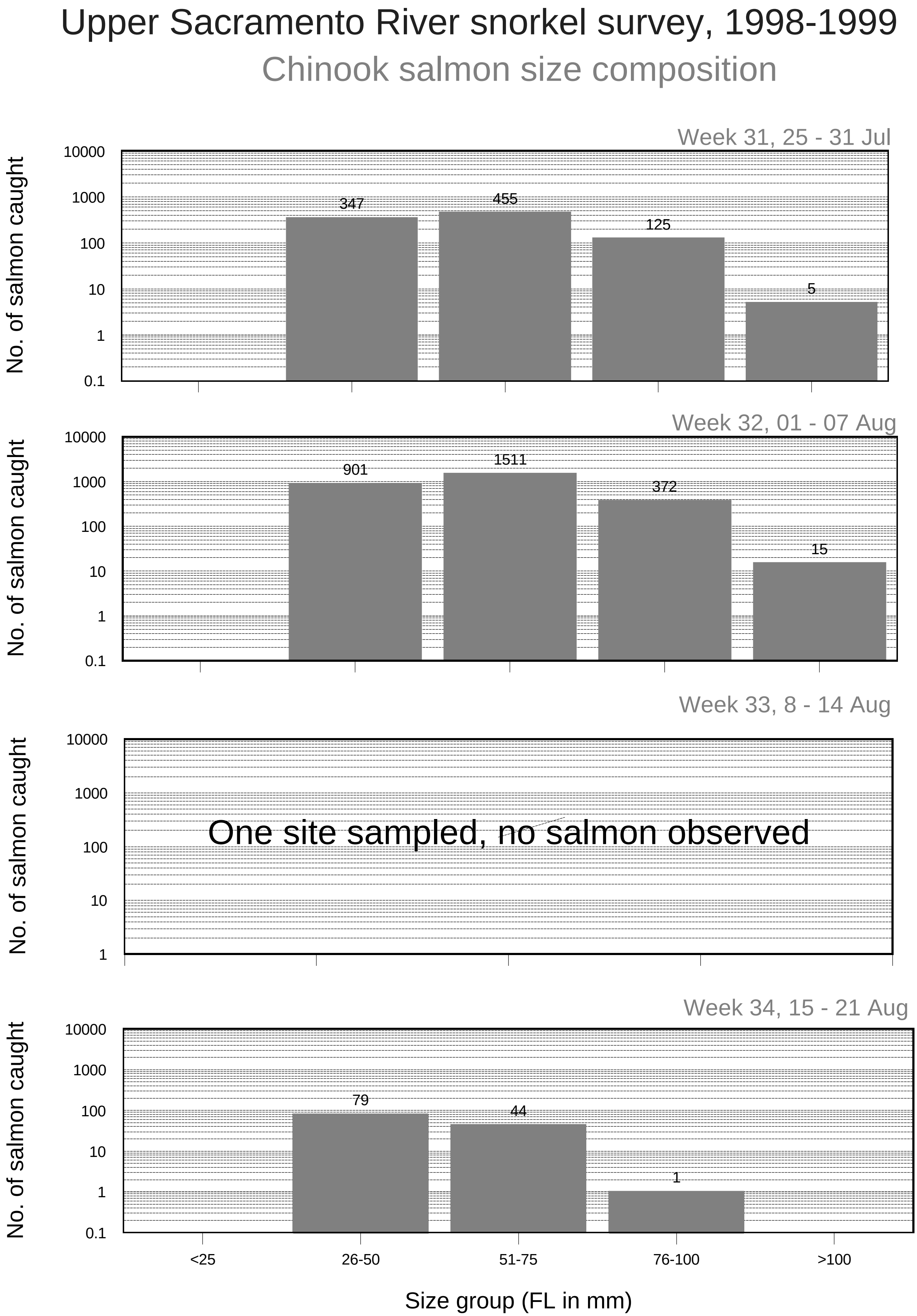


Figure 6. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 25 July - 21 August 1999.

Upper Sacramento River snorkel survey, 1998-1999

Chinook salmon size composition

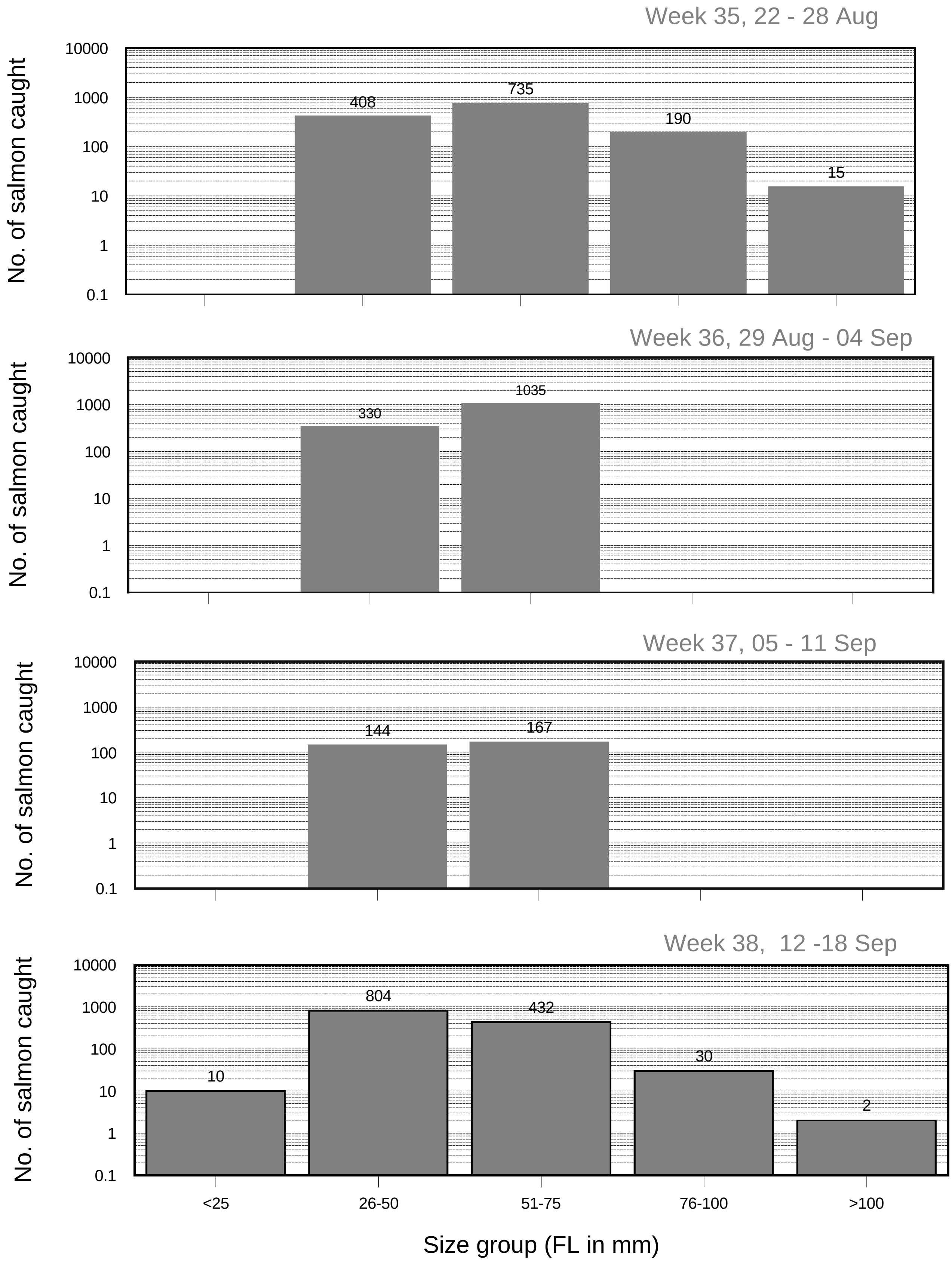


Figure 7. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 22 August -18 September, 1999.

Upper Sacramento River snorkel survey, 1998-1999

Chinook salmon size composition

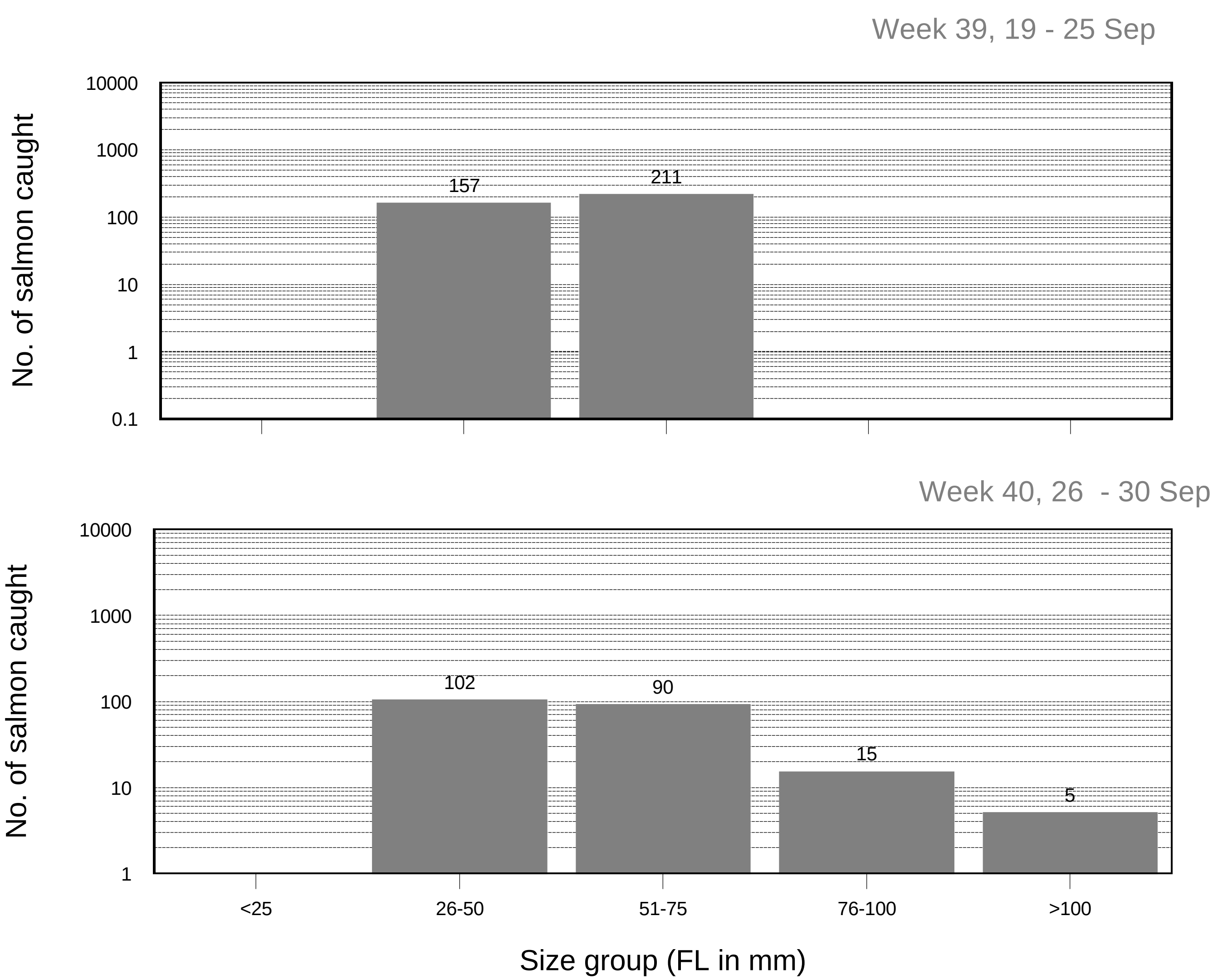


Figure 8. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 19 September - 30 September, 1999.

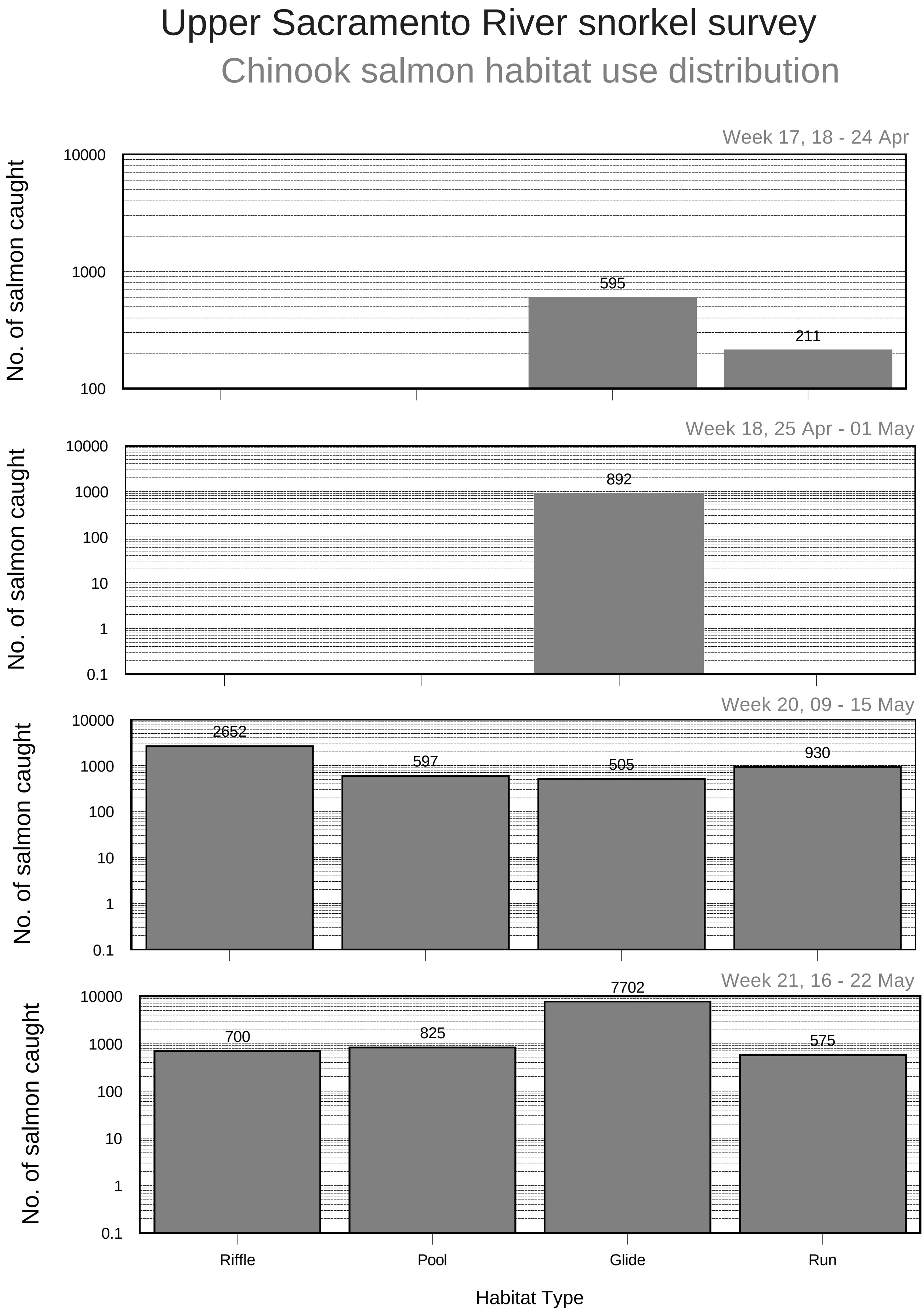


Figure 9. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 18 April - 22 May, 1999.

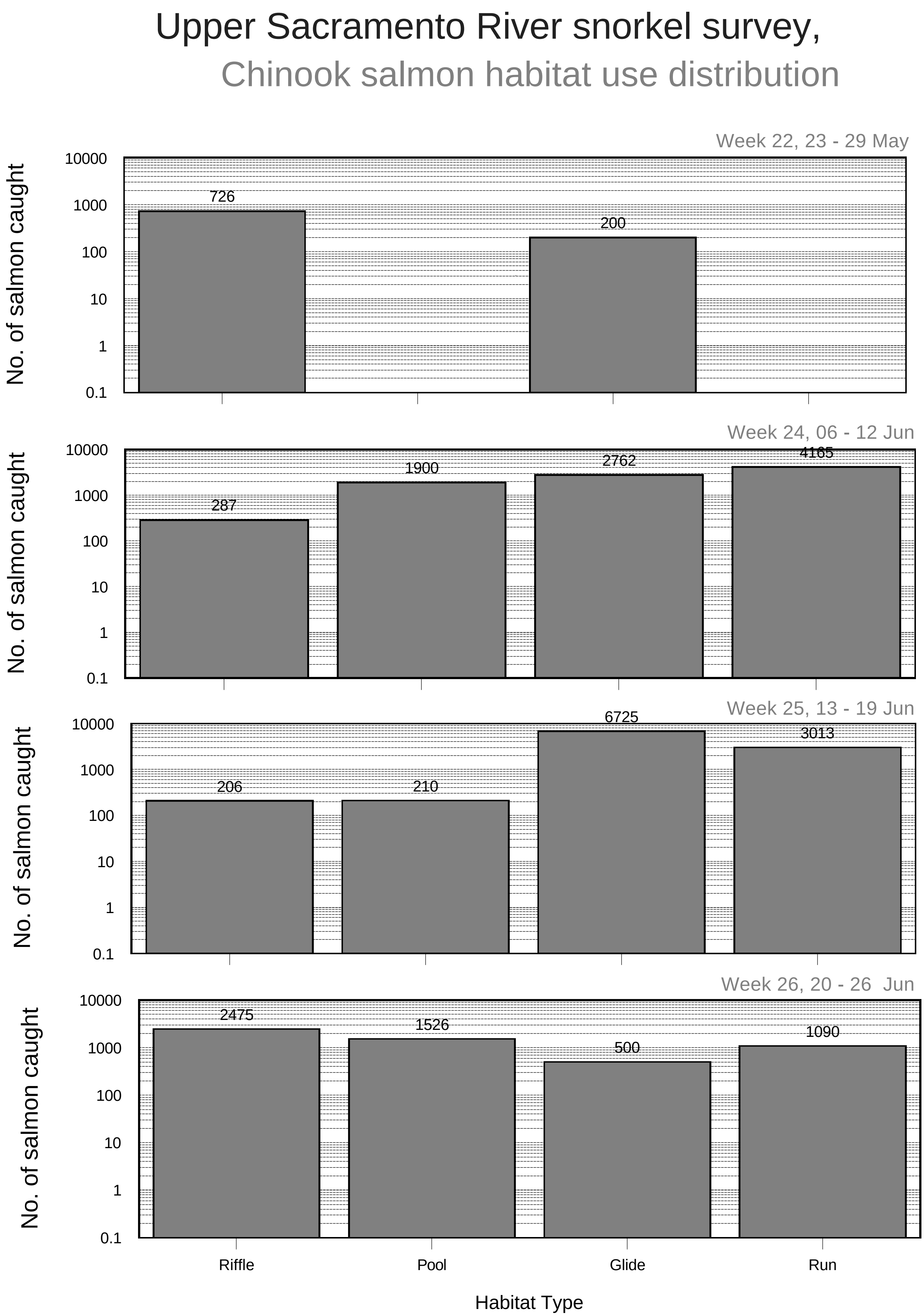


Figure 10. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 23 May - 26 June, 1999.

Upper Sacramento River snorkel survey,
Chinook salmon habitat use distribution

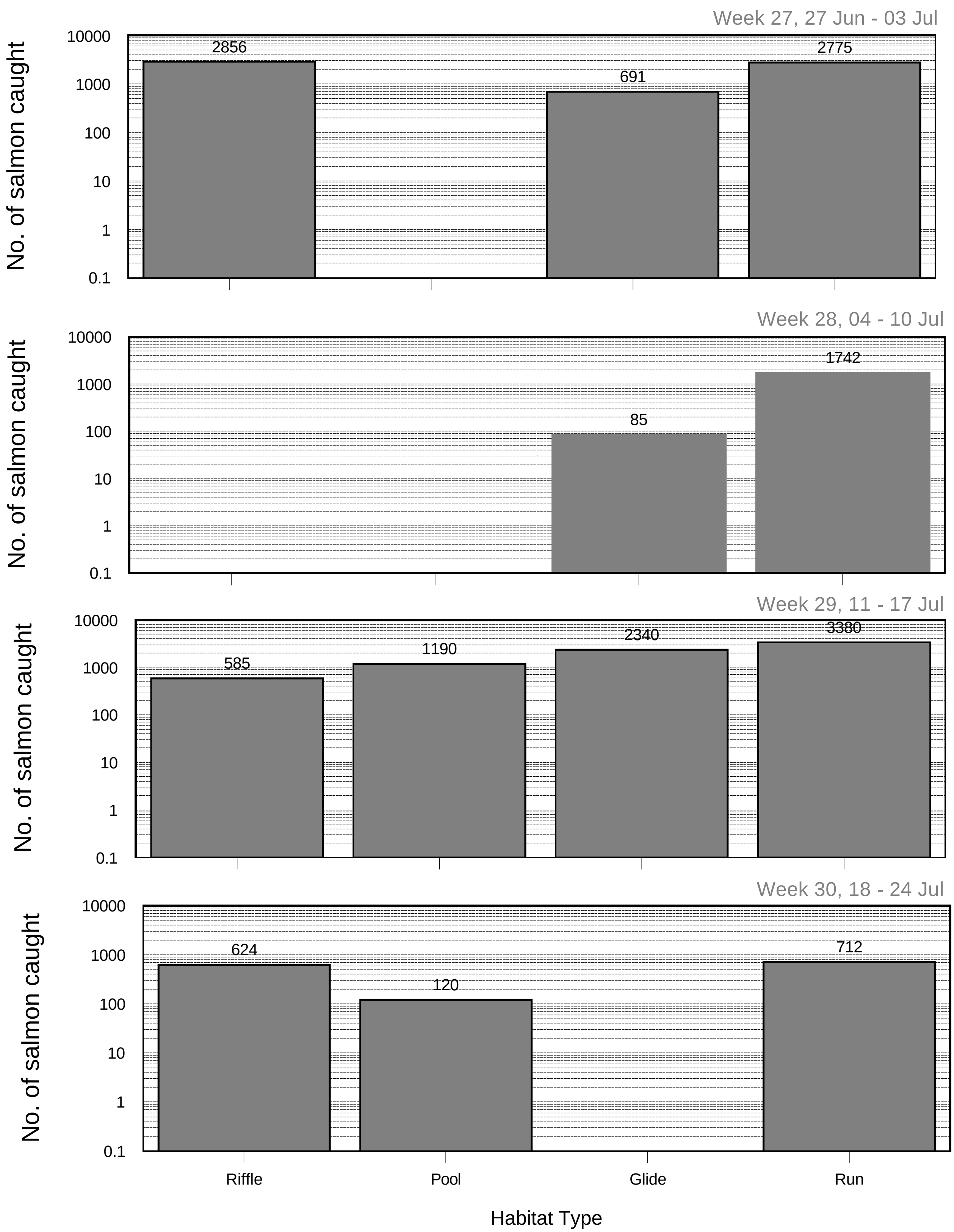


Figure 11. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 27 June - 24 July, 1999.

Upper Sacramento River snorkel survey

Chinook salmon habitat use distribution

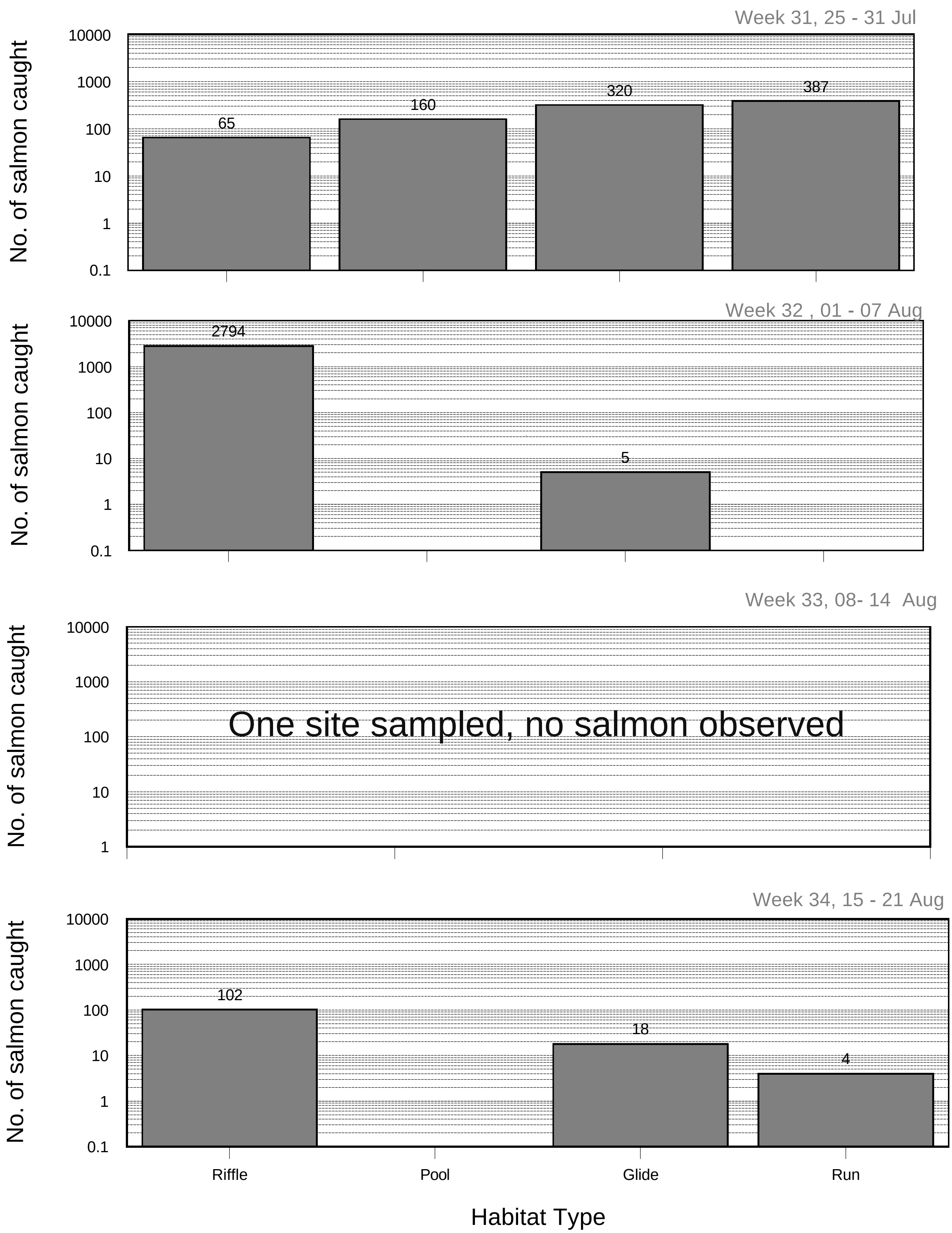


Figure 12. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 25 July - 21 August 1999.

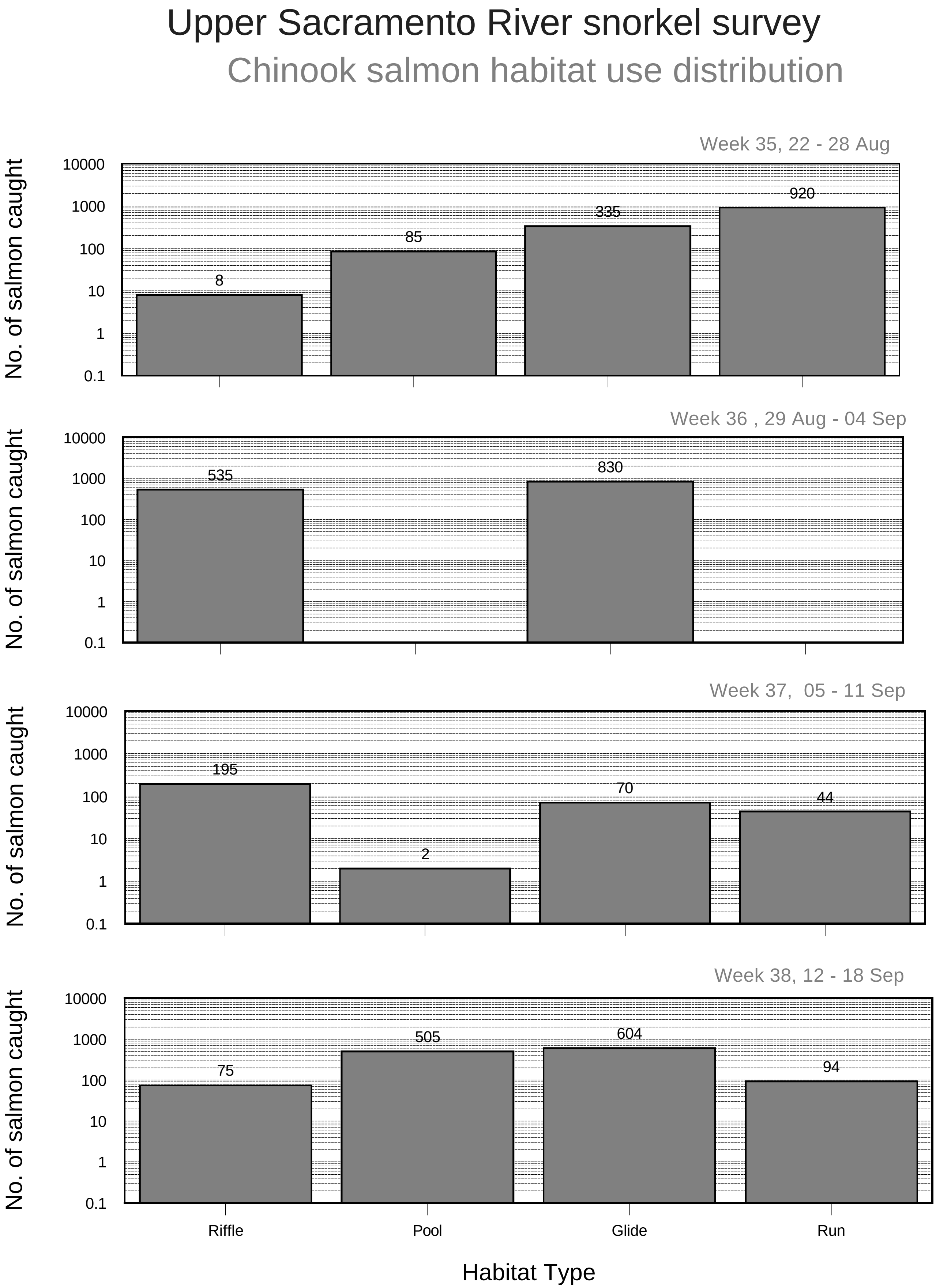


Figure 13. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 22 August - 18 September, 1999.

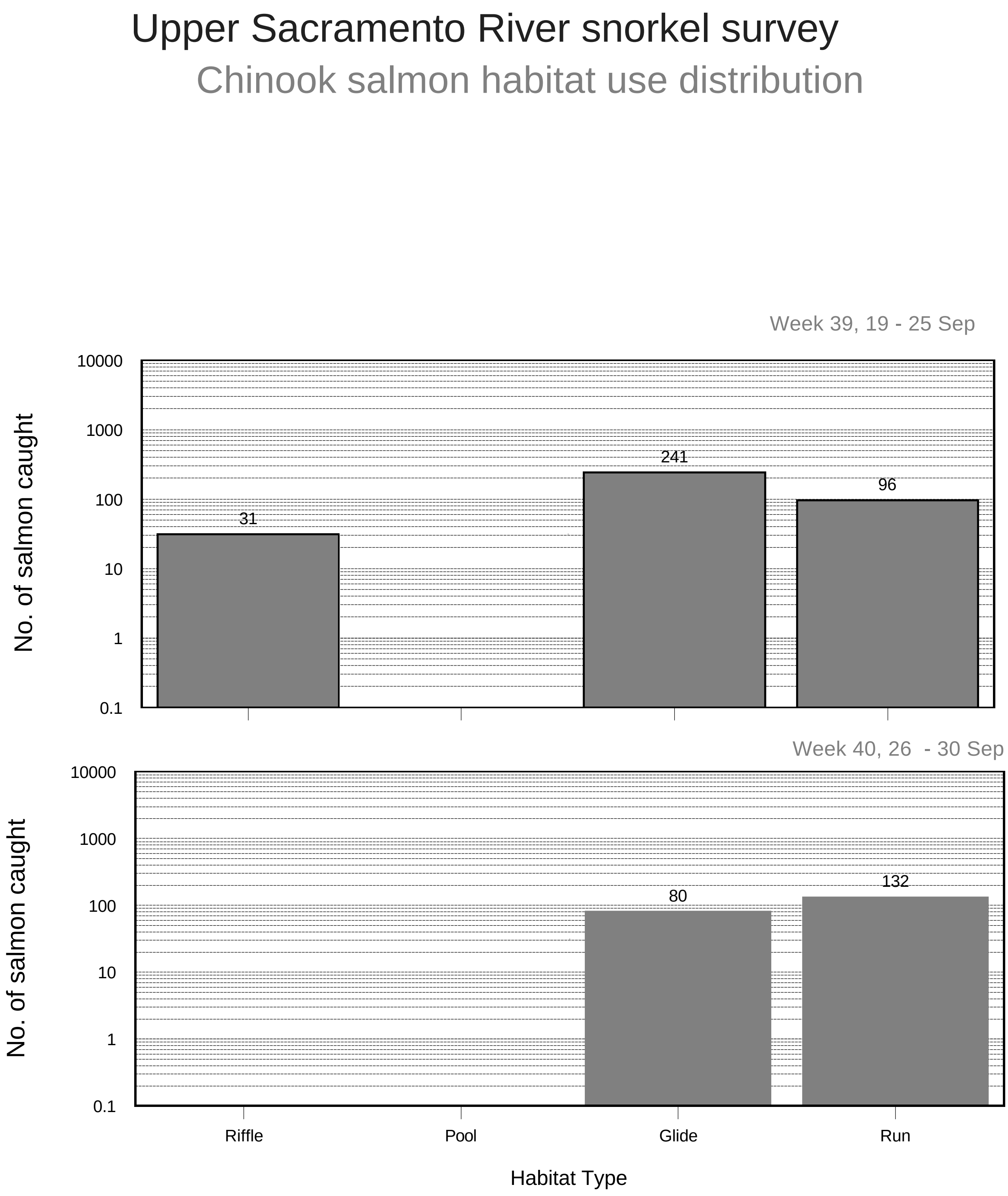


Figure 14. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 19 September - 30 September, 1999.

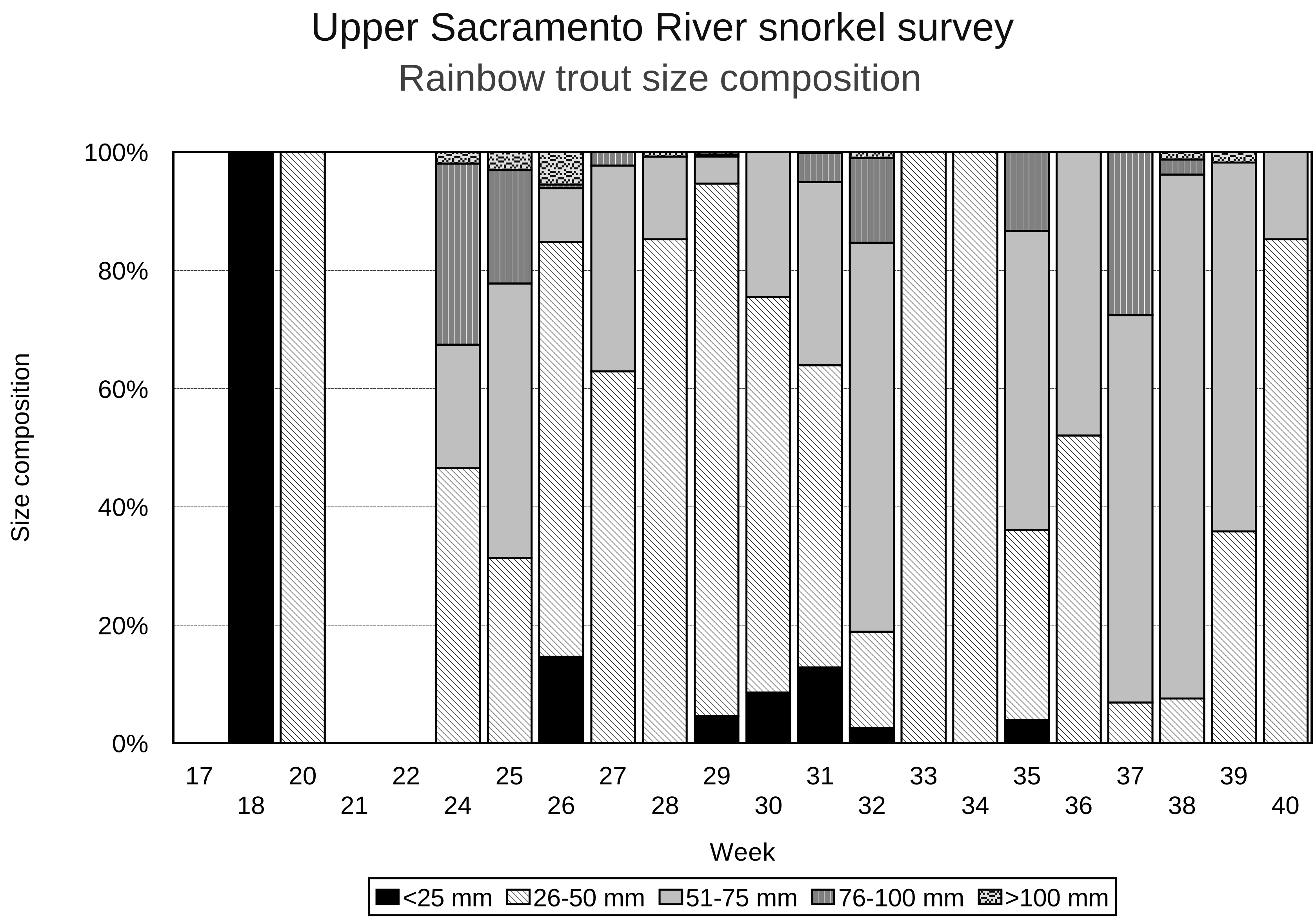


Figure 15. Weekly size composition of steelhead observed during the upper Sacramento River snorkel survey, October 1998 - September 1999. No sites were sampled Week 41- Week 16.

Upper Sacramento River snorkel survey, 1998-1999

Rainbow trout size composition

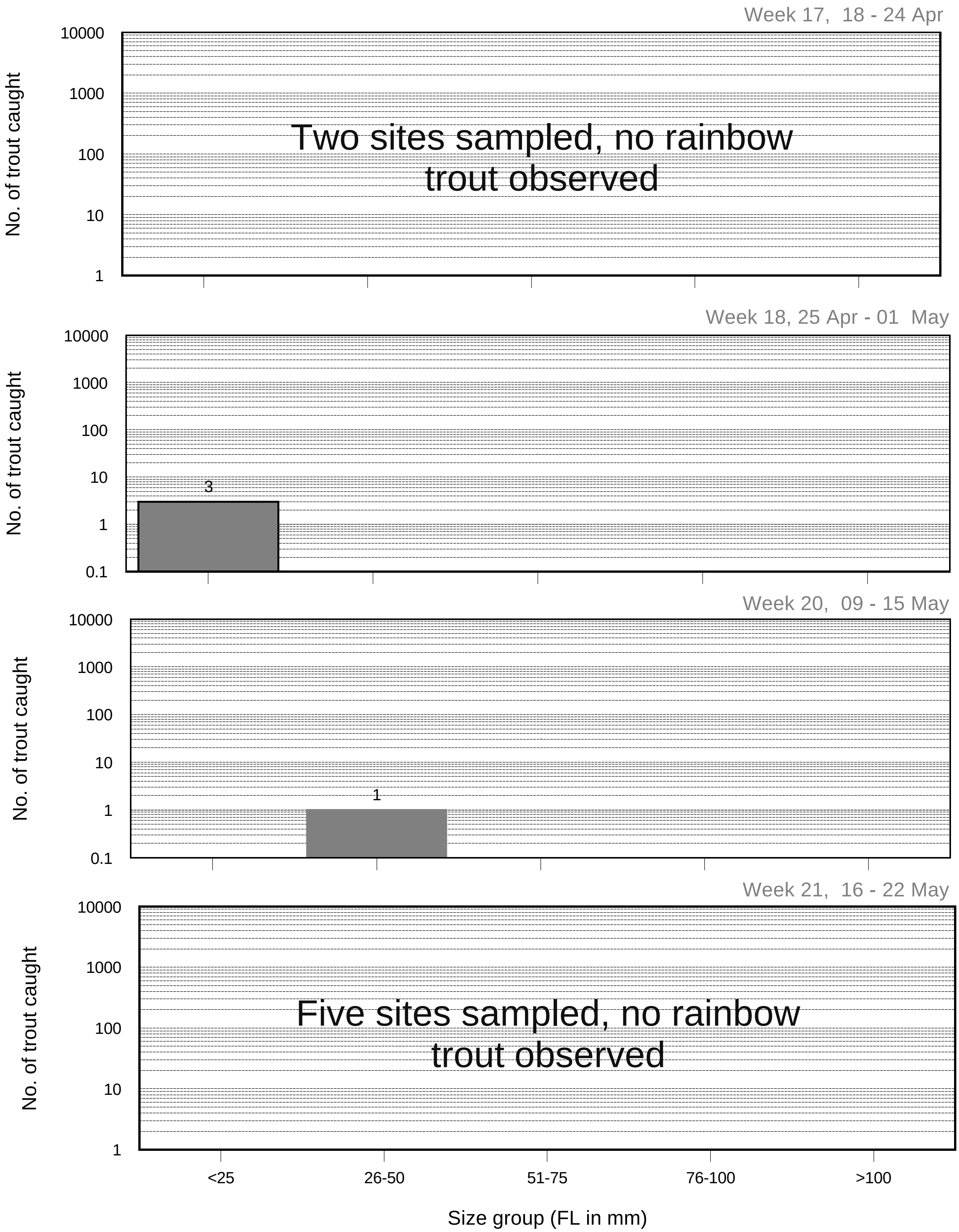


Figure 16. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 18 April - 22 May 1999. No rainbow trout observed in weeks 17, 21, and 22.

Upper Sacramento River snorkel survey, 1998-1999

Rainbow trout size composition

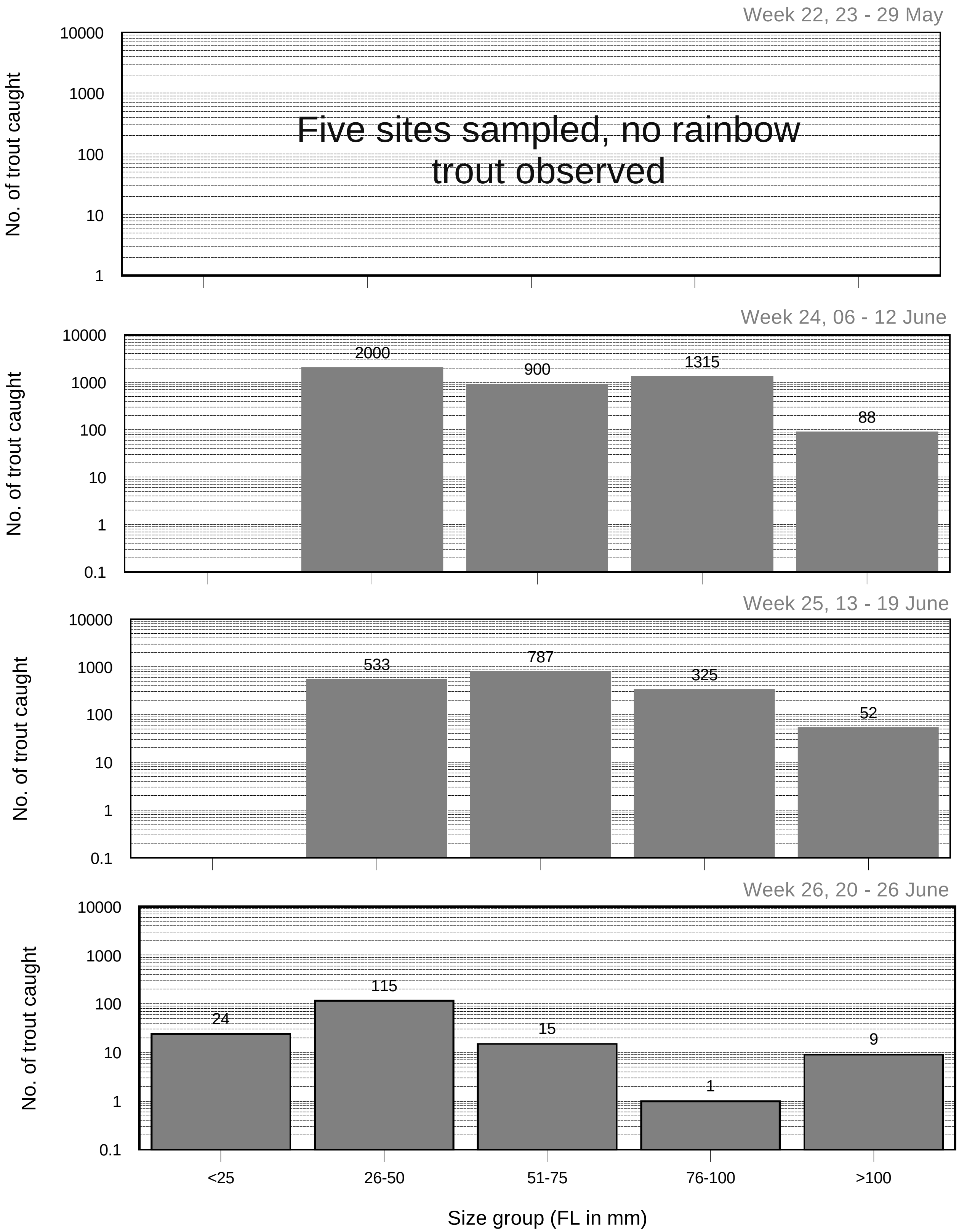


Figure 17. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 23 May - 26 June 1999. No rainbow trout observed in weeks 17, 21, and 22.

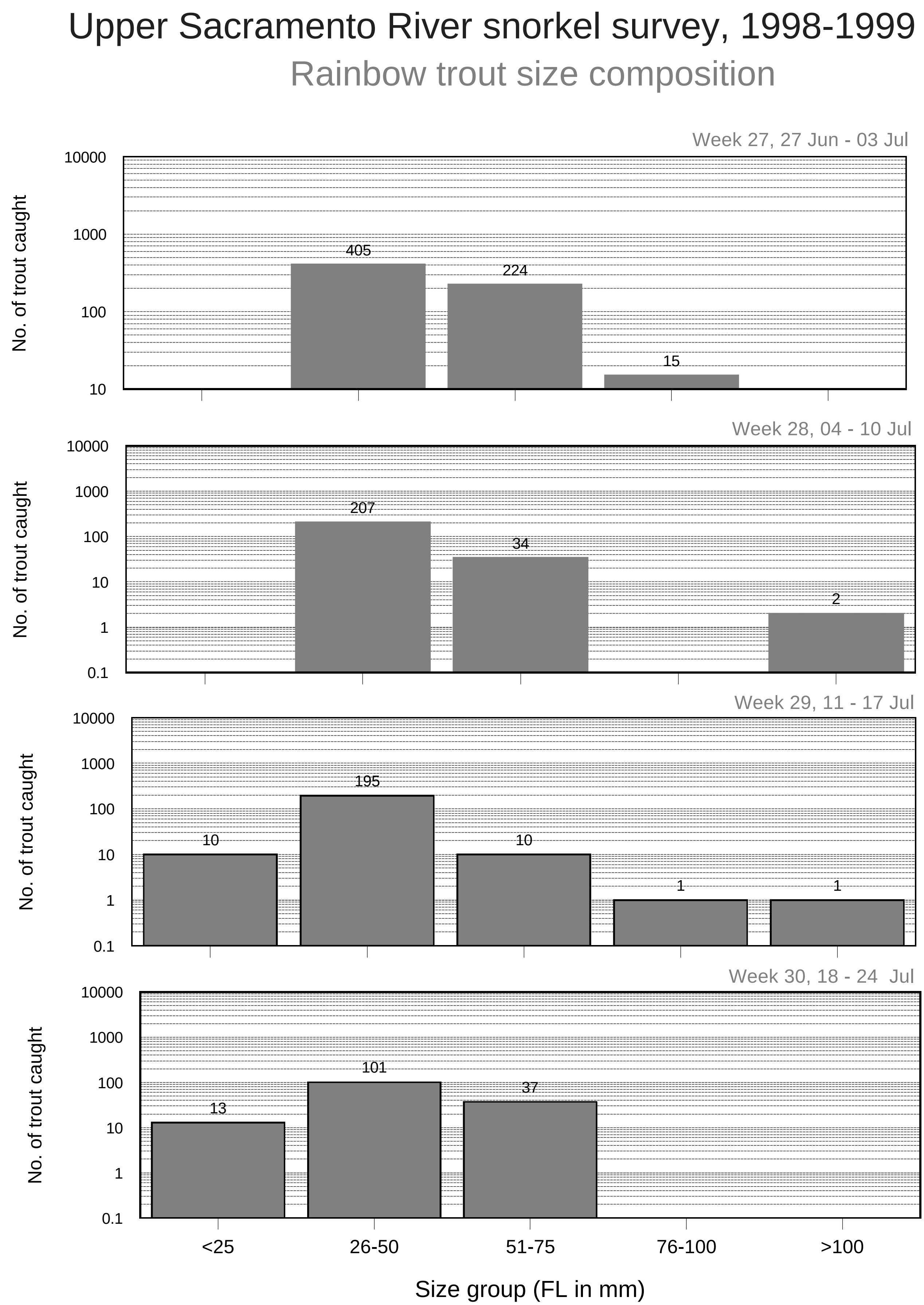


Figure 18. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 27 June - 24 July, 1999.

Upper Sacramento River snorkel survey, 1998-1999

Rainbow trout size composition

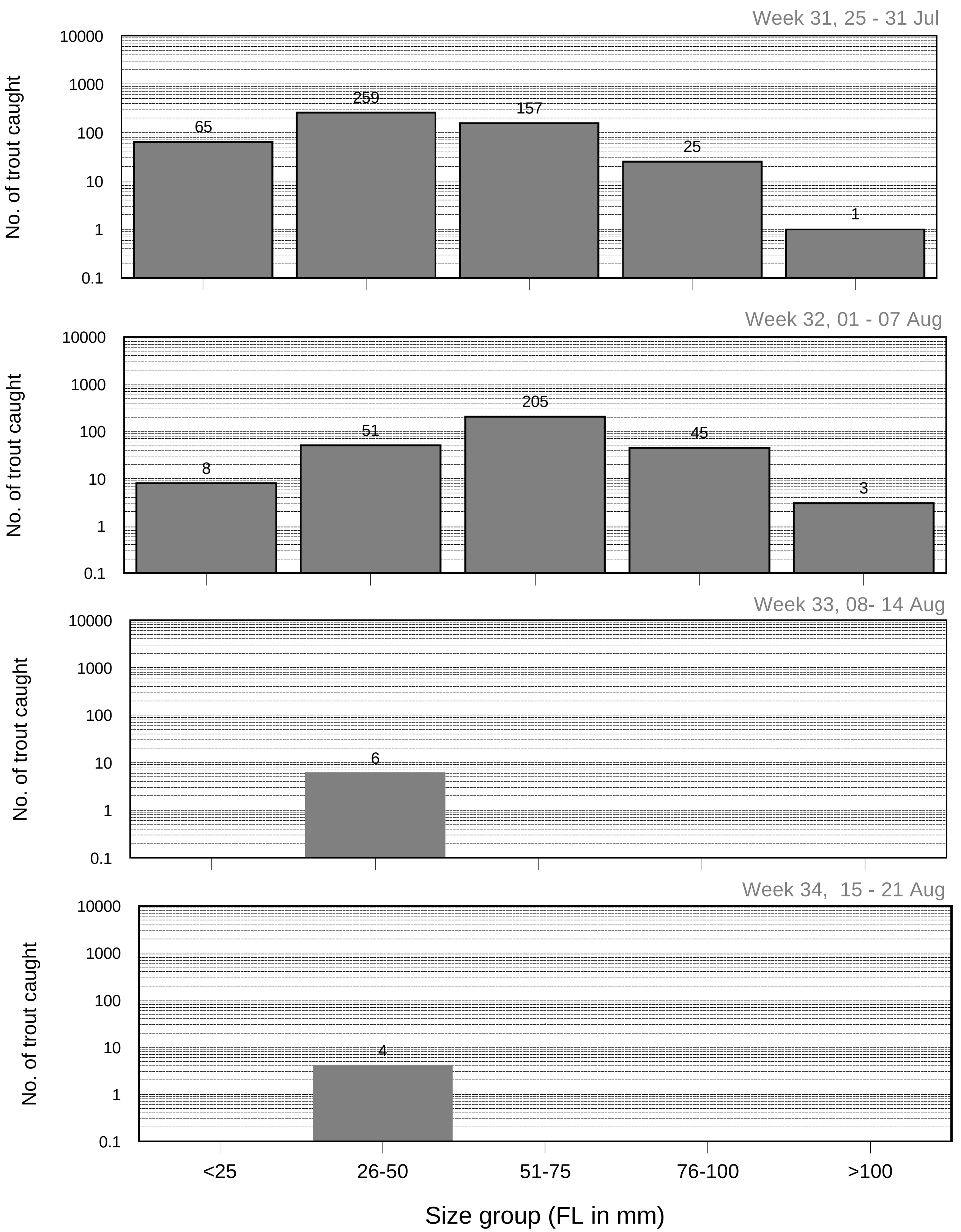


Figure 19. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 25 July - 21 August, 1999.

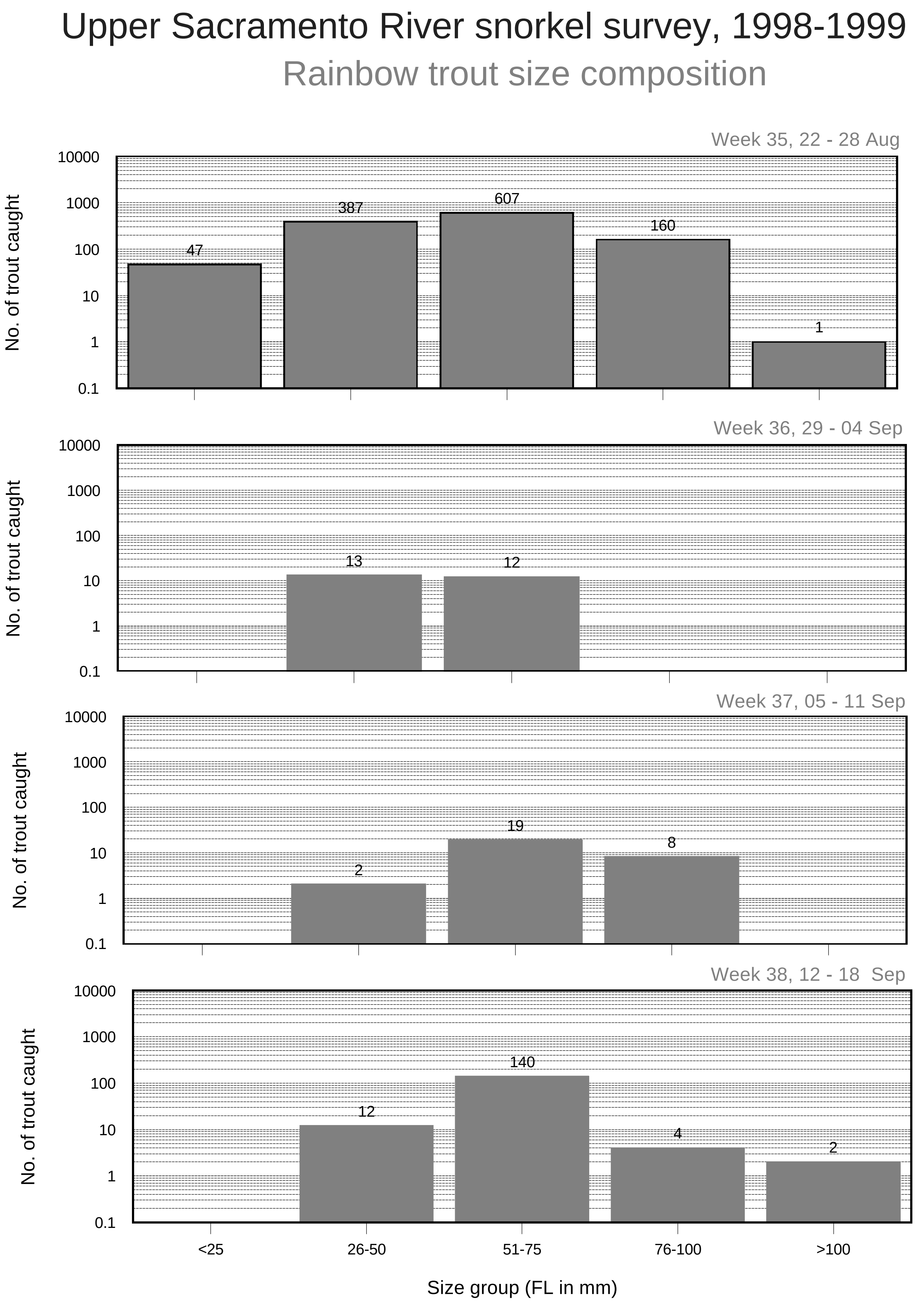


Figure 20. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 22 August - 18 September, 1999.

Upper Sacramento River snorkel survey, 1998-1999

Rainbow trout size composition

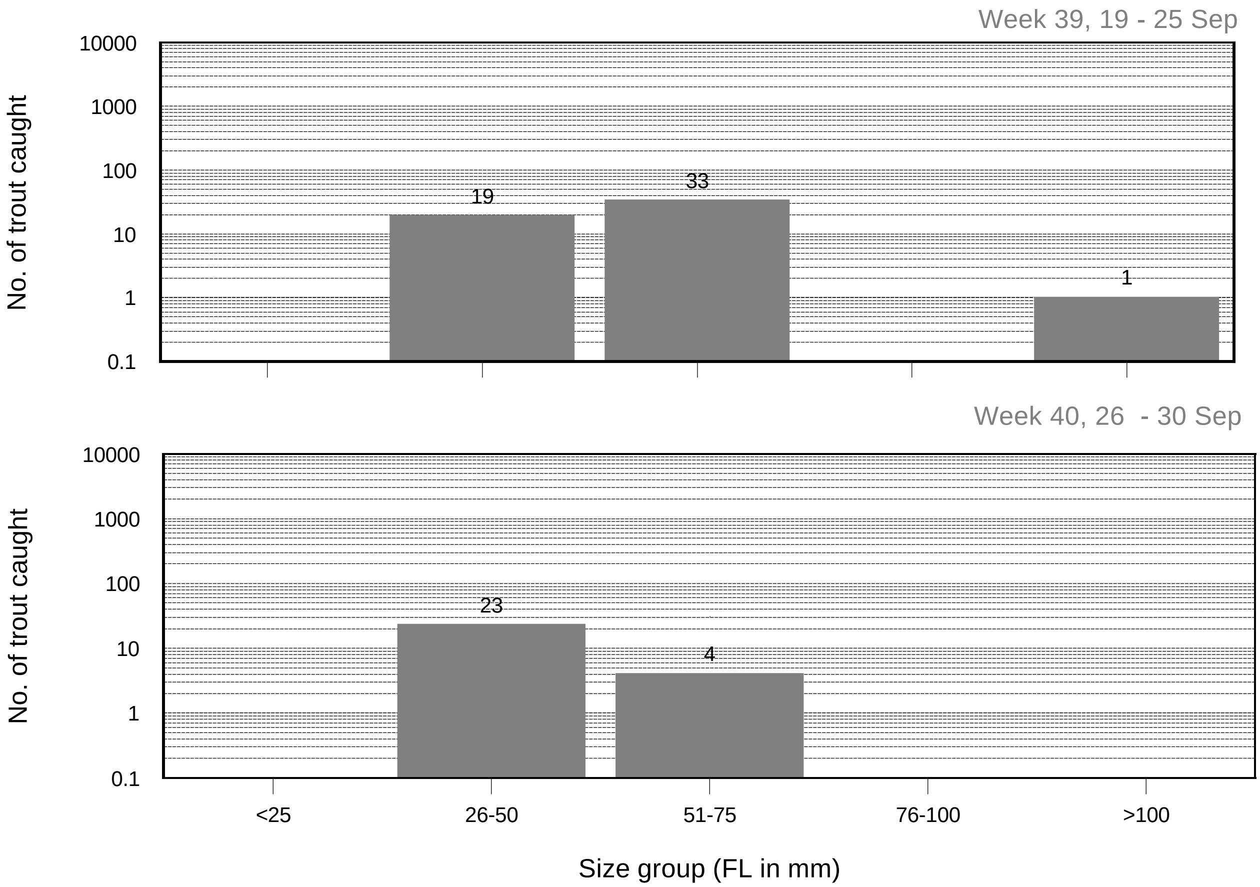


Figure 21. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 26 September - 30 September, 1999.

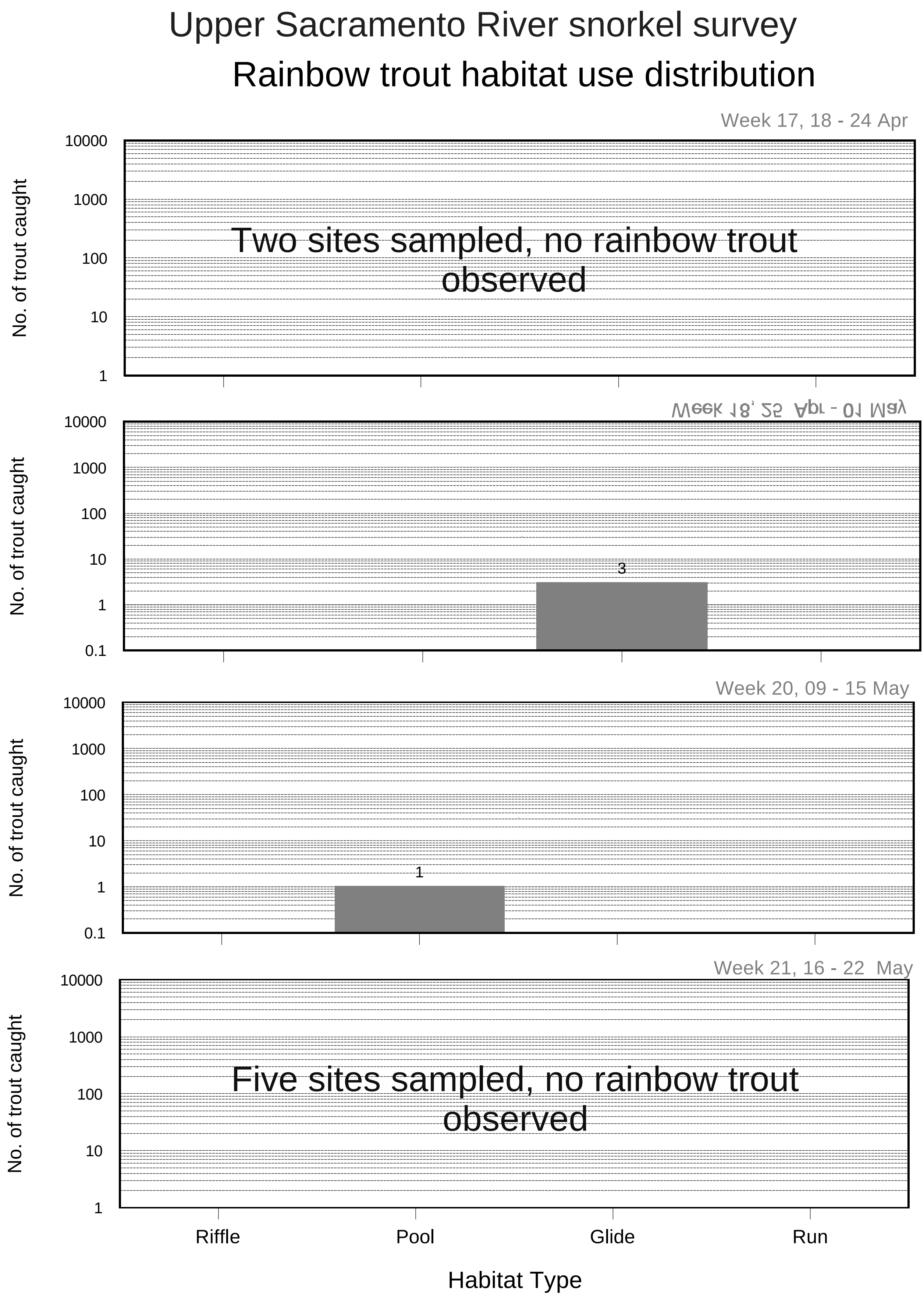


Figure 22. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 18 April - 22 May, 1999. No rainbow trout observed in weeks 17, 21, 22.

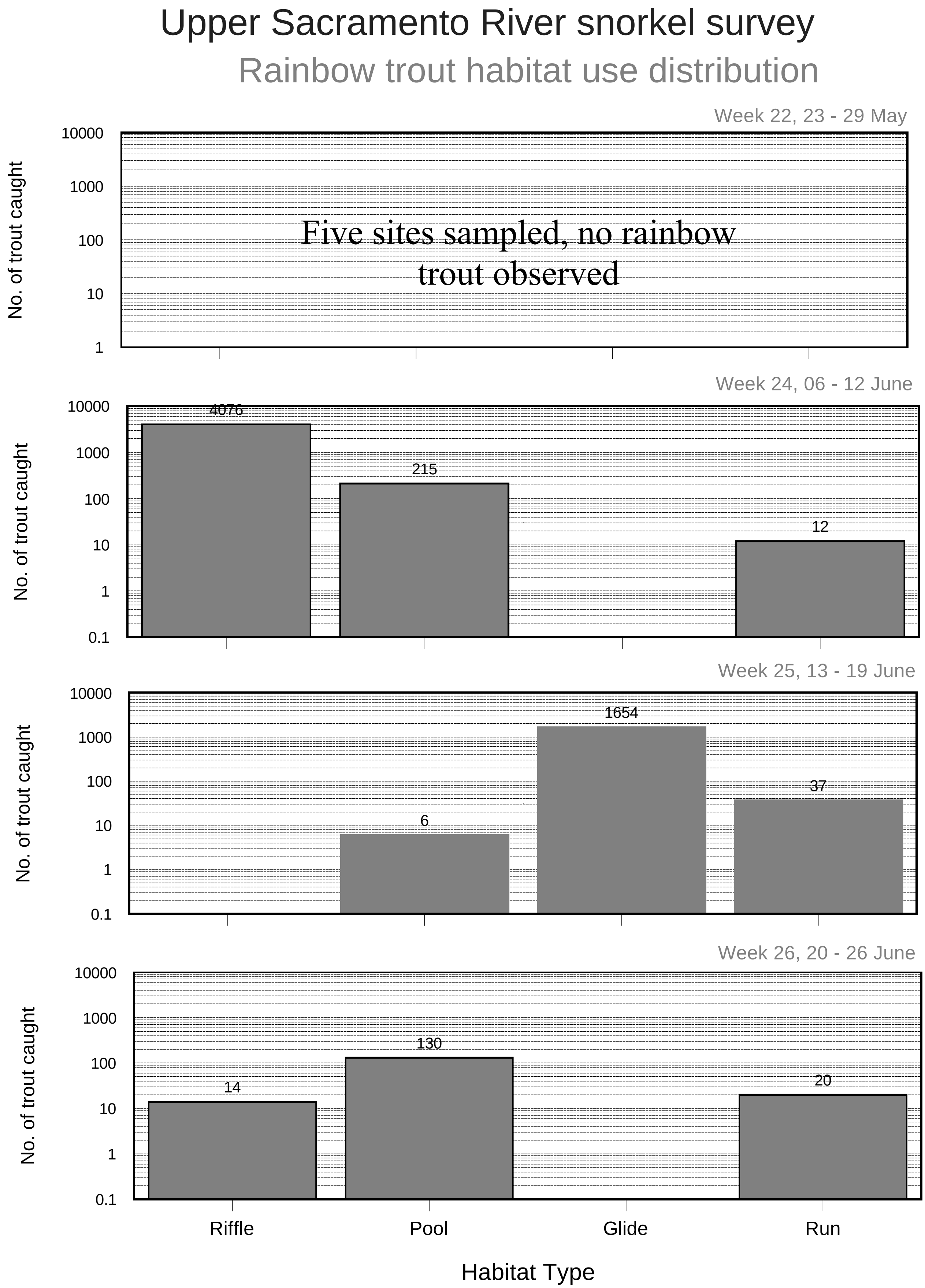


Figure 23. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 23 May - 26 June, 1999. No rainbow trout observed in weeks 17, 21, 22.

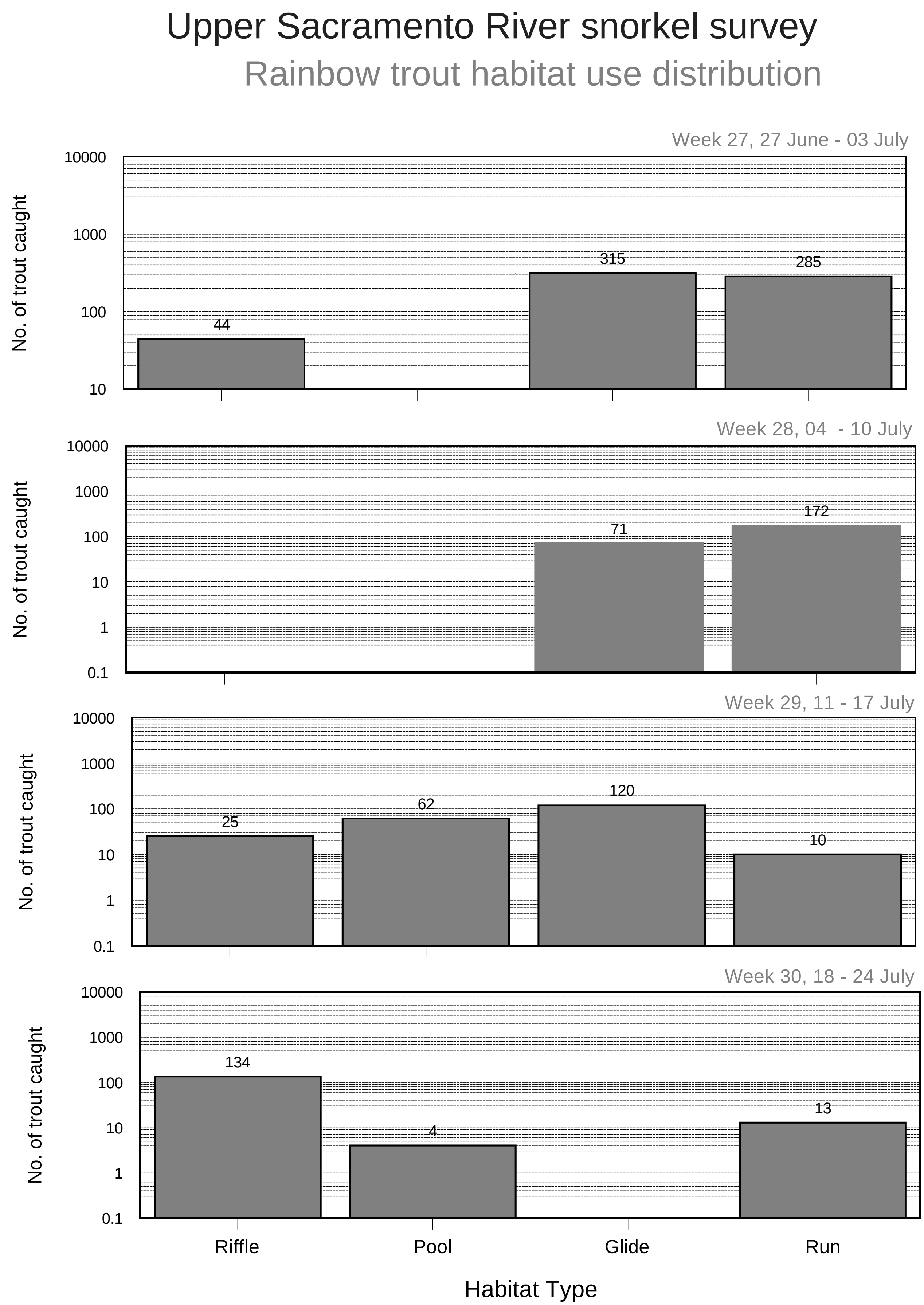


Figure 24. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 27 June - 24 July, 1999.

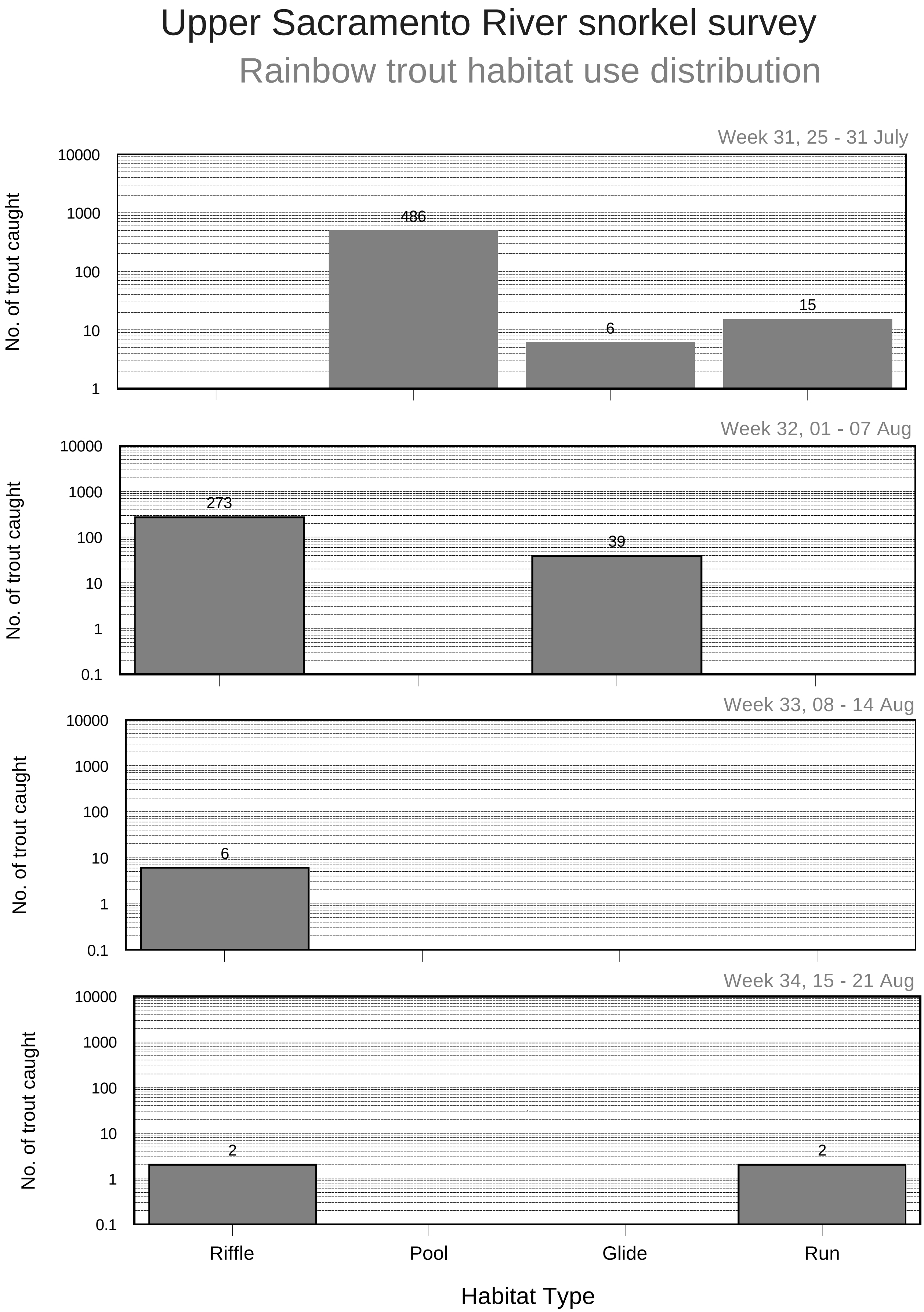


Figure 25. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 25 July- 21 August, 1999.

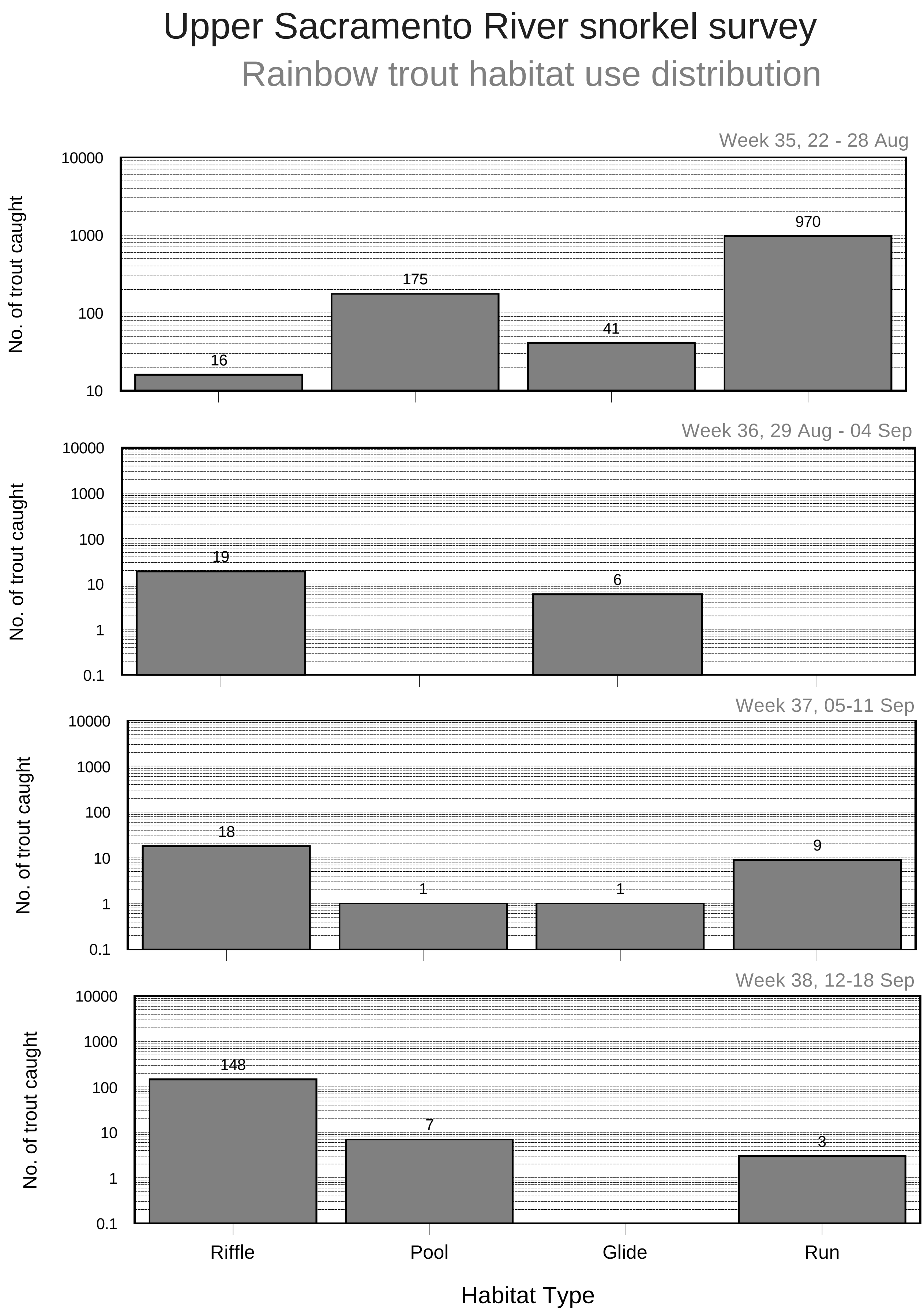


Figure 26. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 22 August - 18 September, 1999.

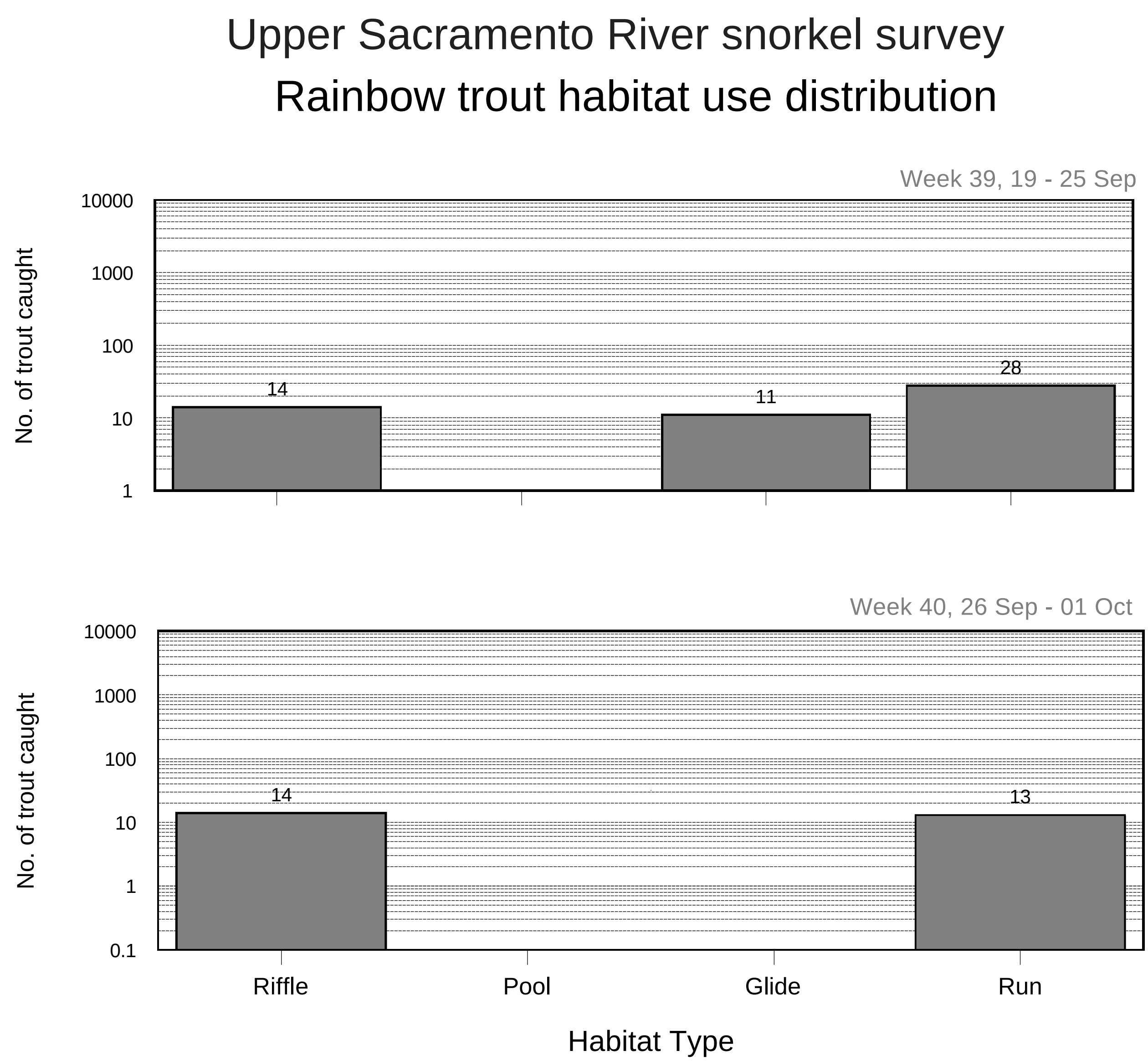


Figure 27. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 19 September - 01 October, 1999.

Upper Sacramento River seining survey

Chinook salmon fork length distribution

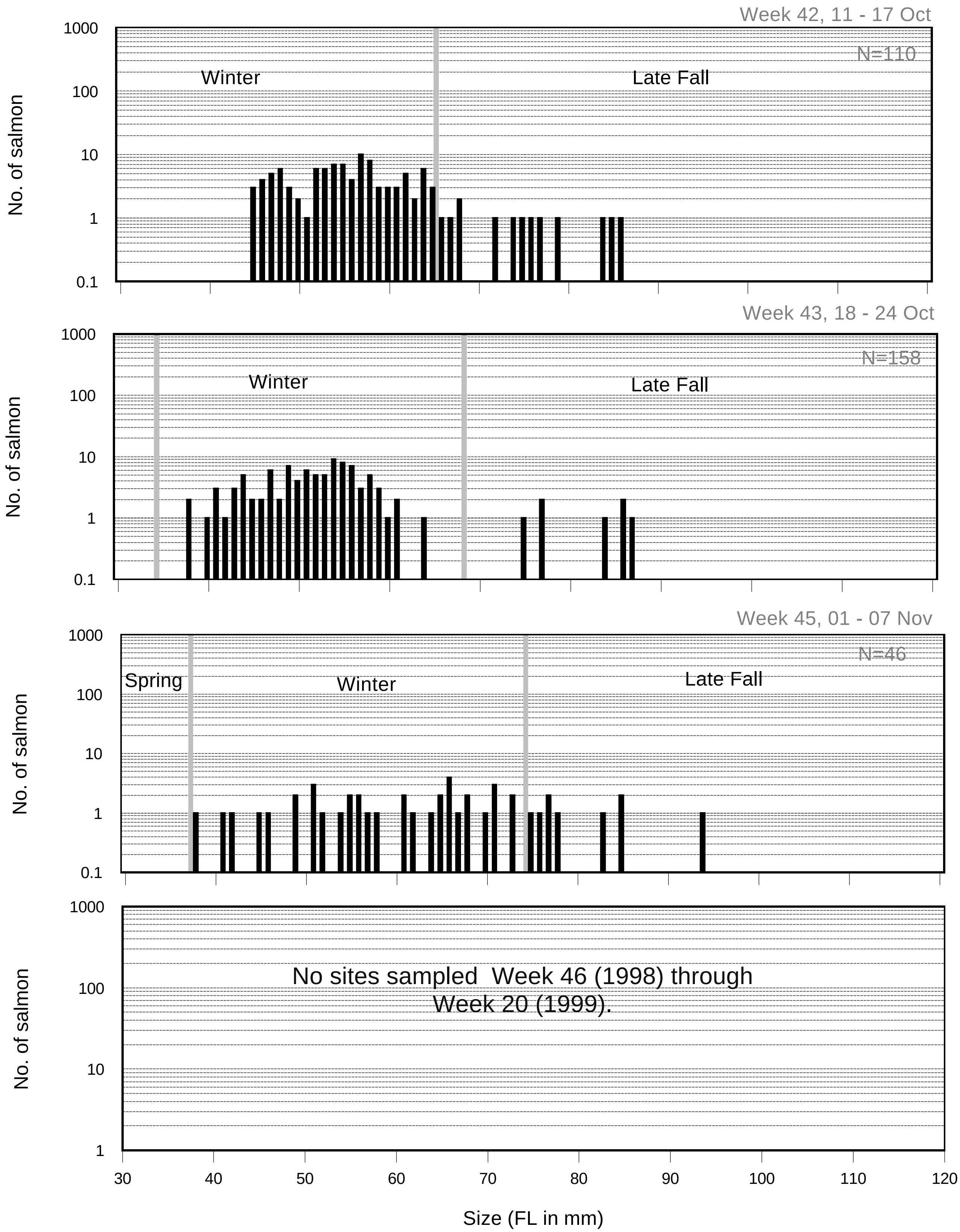


Figure 28. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 11 October, 1998 - 15 May 1999.

Upper Sacramento River seining survey

Chinook salmon fork length distribution

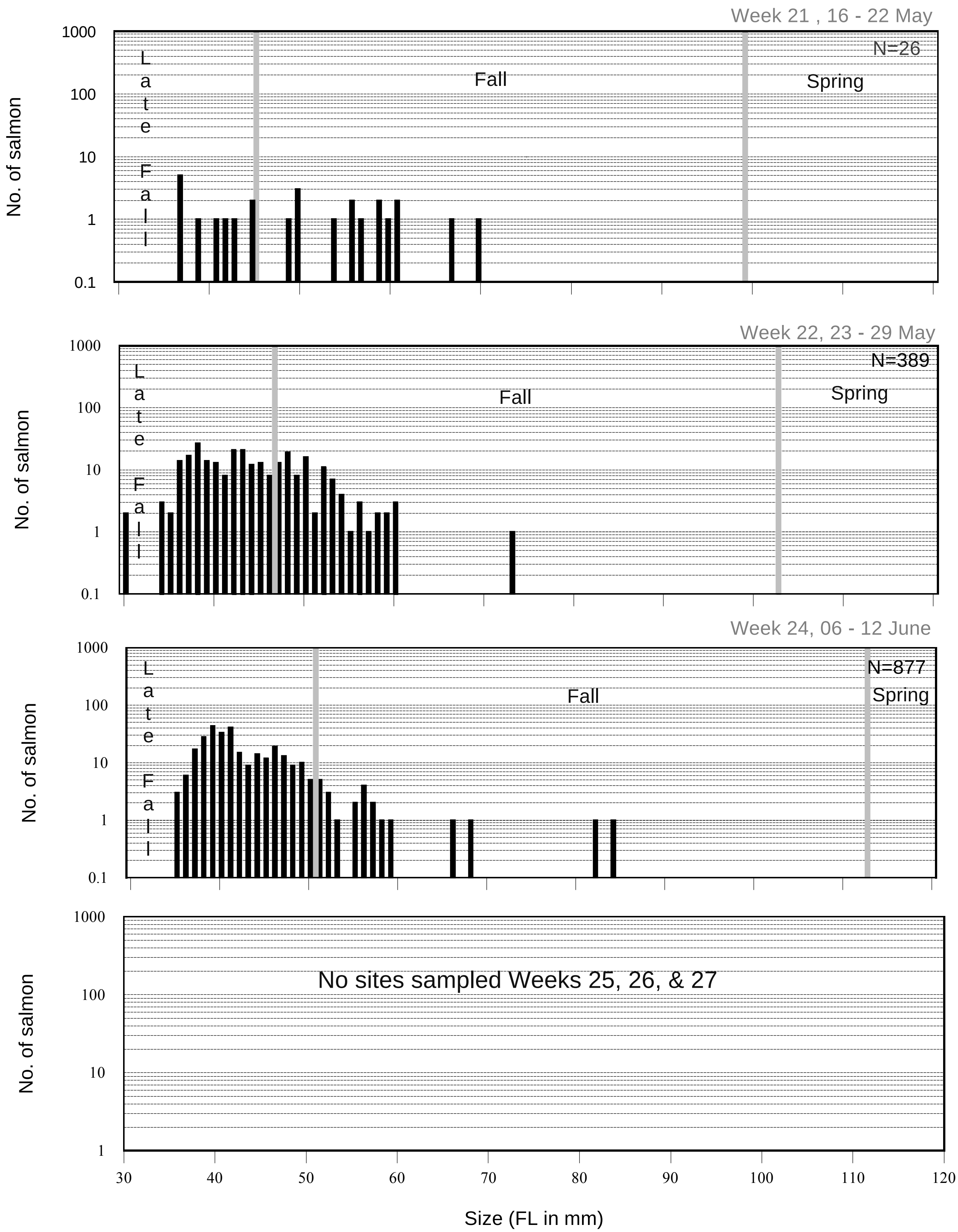


Figure 29. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 16 May - 3 July, 1999.

Upper Sacramento River seining survey

Chinook salmon fork length distribution

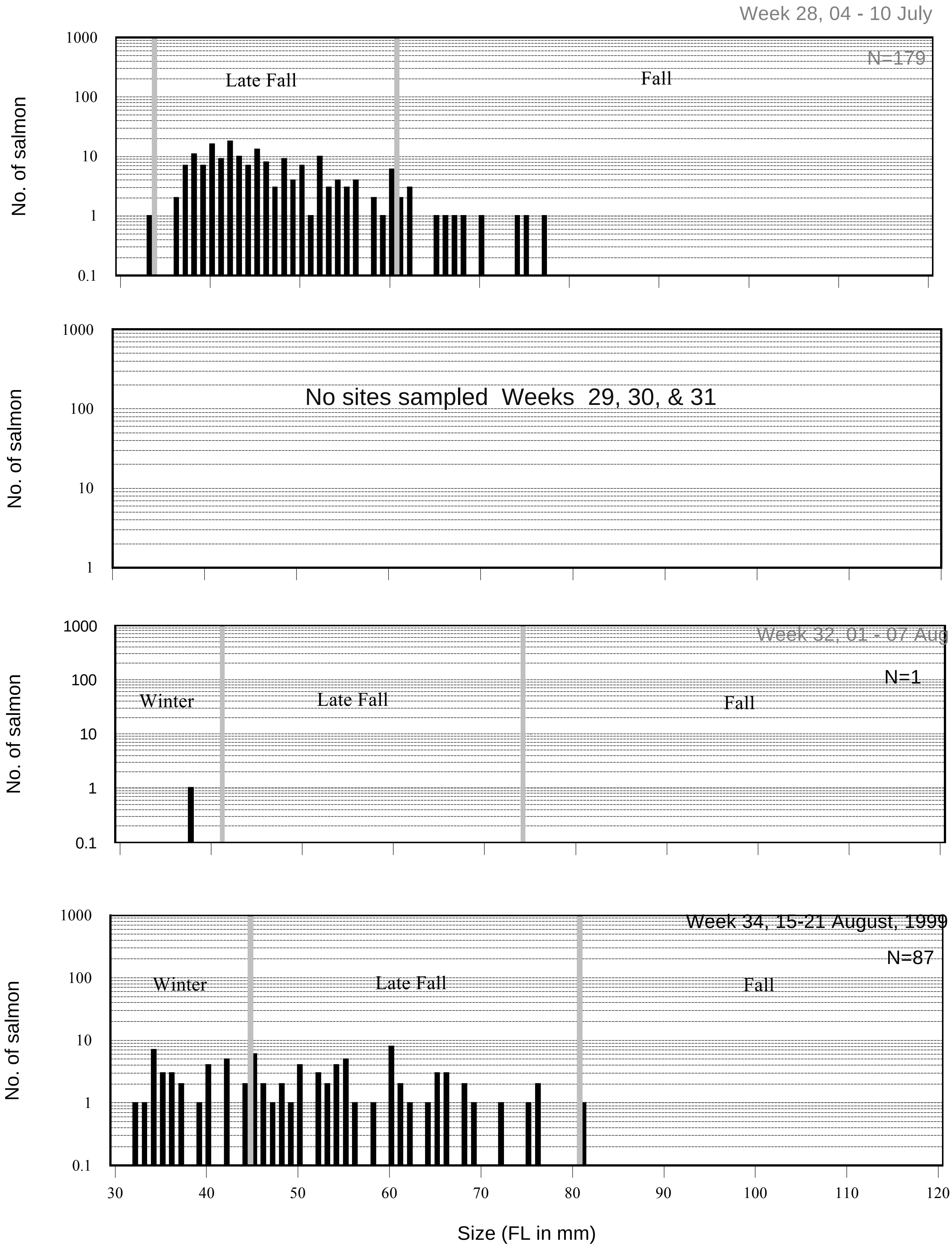


Figure 30. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 4 July - 21 August 1999.

Upper Sacramento River seining survey
Chinook salmon fork length distribution

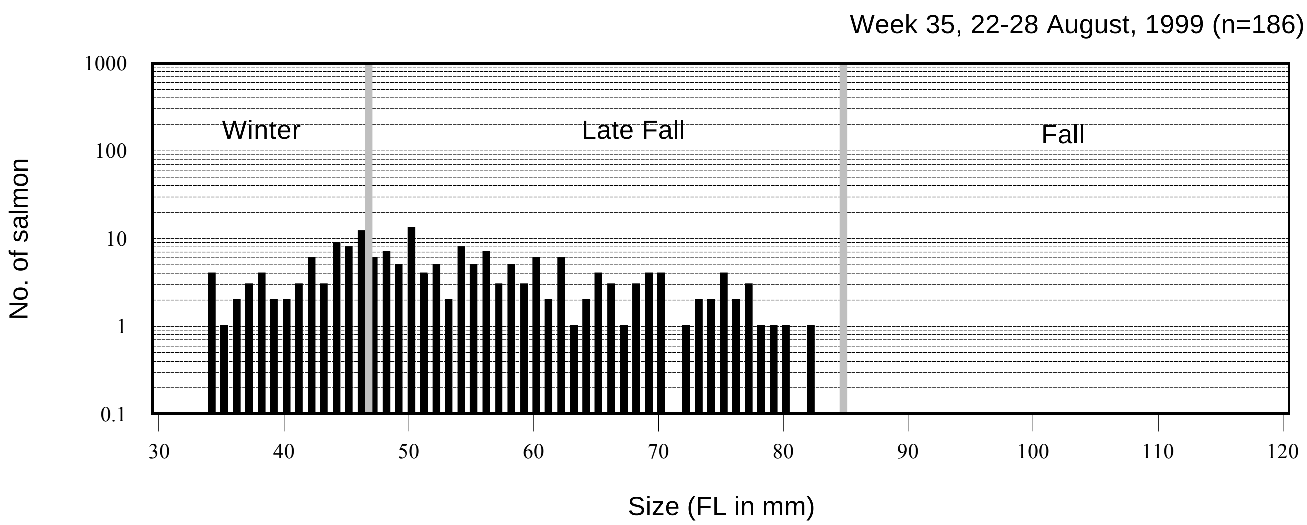


Figure 31. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 22 August - 28 August 1999.

Upper Sacramento River seining survey

Rainbow trout fork length distribution

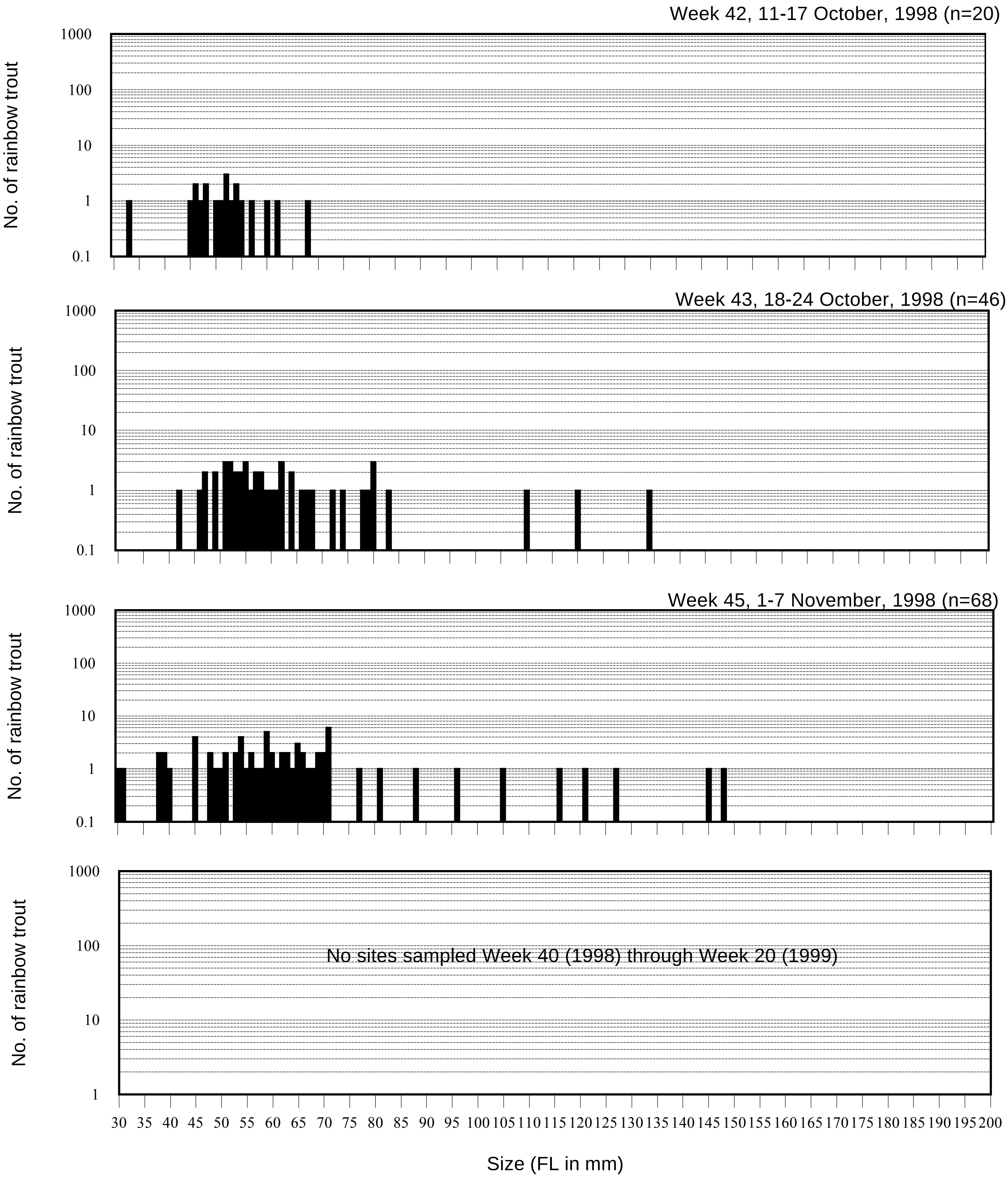


Figure 32. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 11 October 1998 - 5 June 1999.

Upper Sacramento River seining survey
Rainbow trout fork length distribution

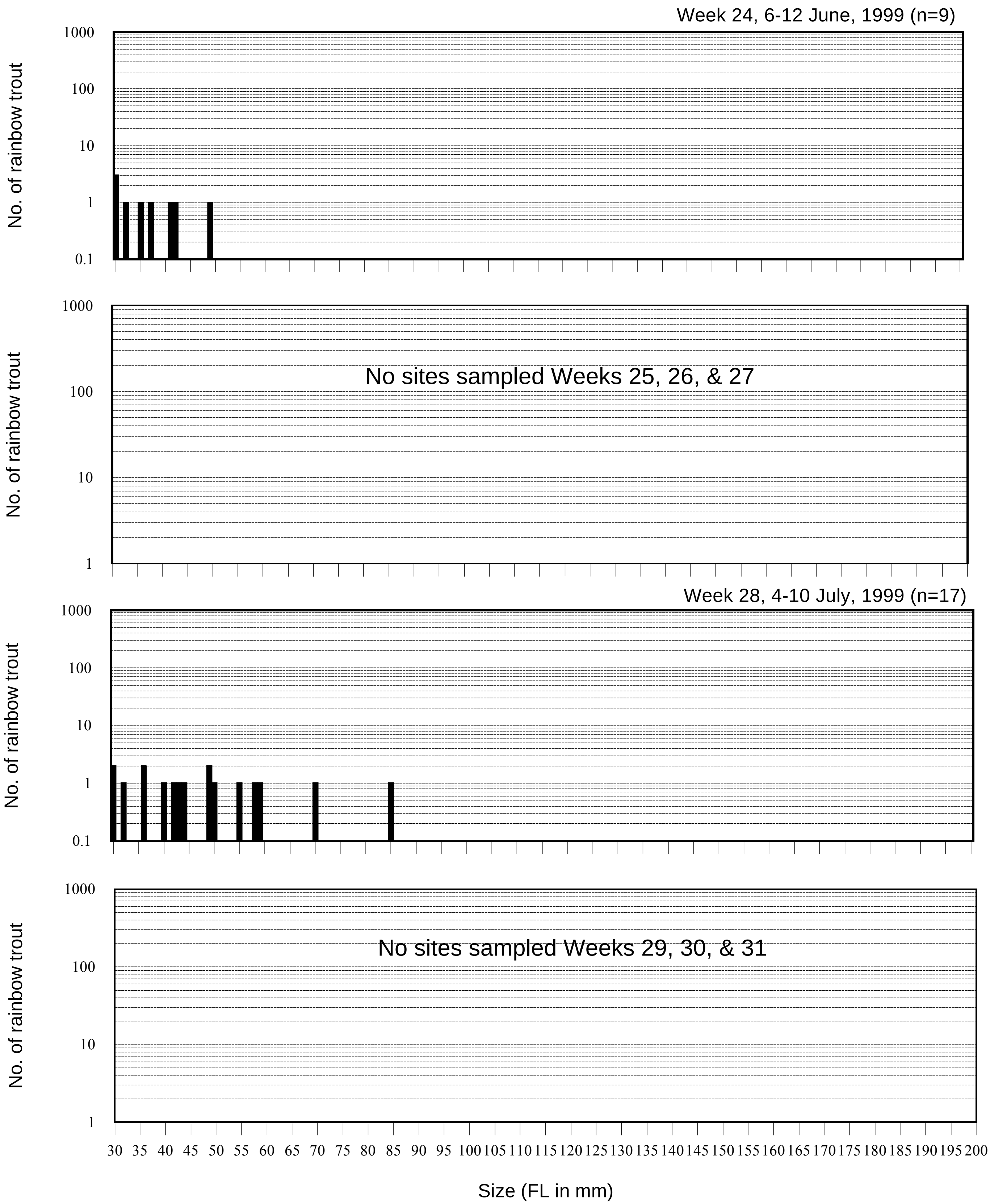


Figure 33. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 6 June - 31 July 1999.

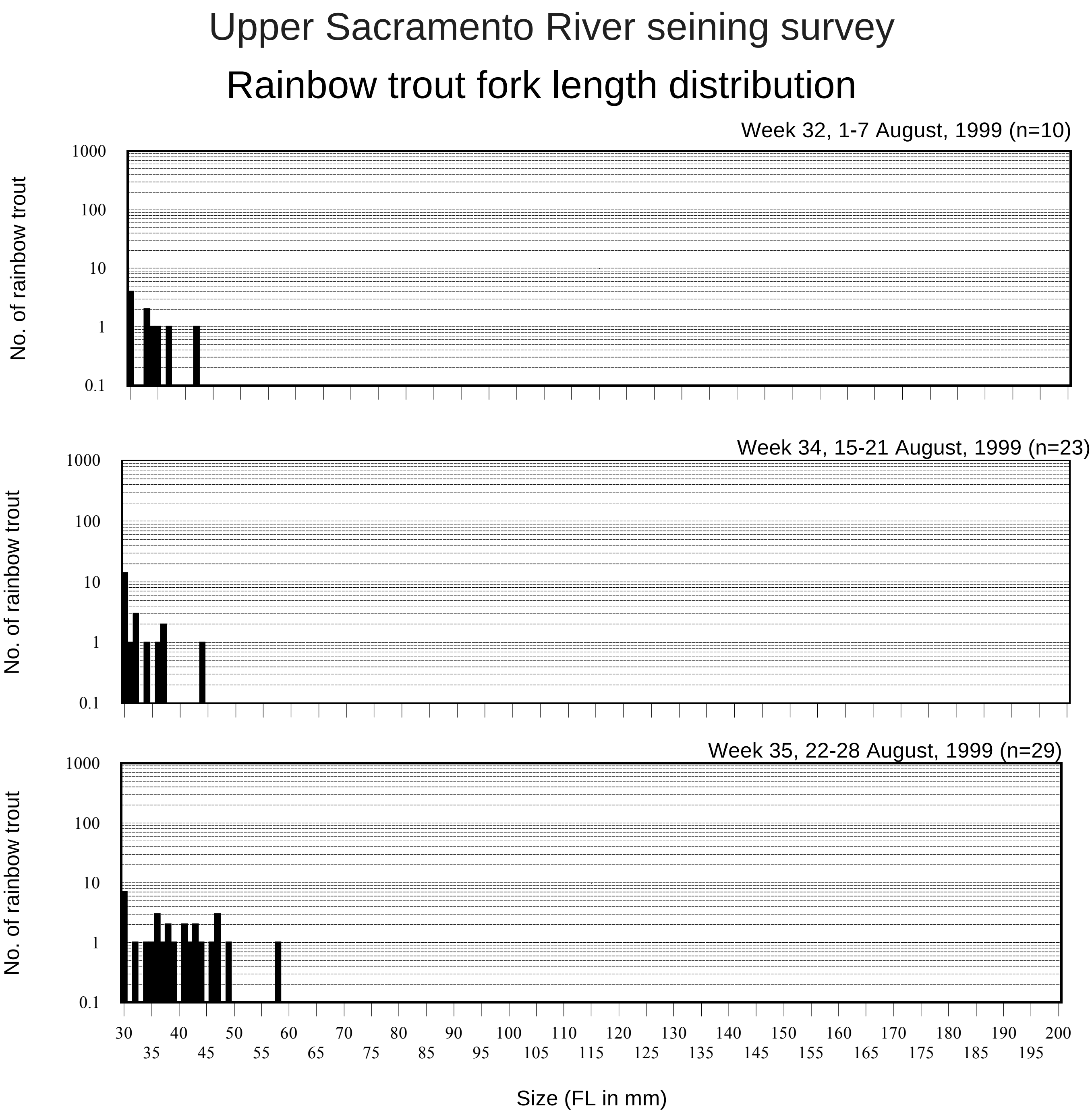


Figure 34. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 1 - 28 August 1999.

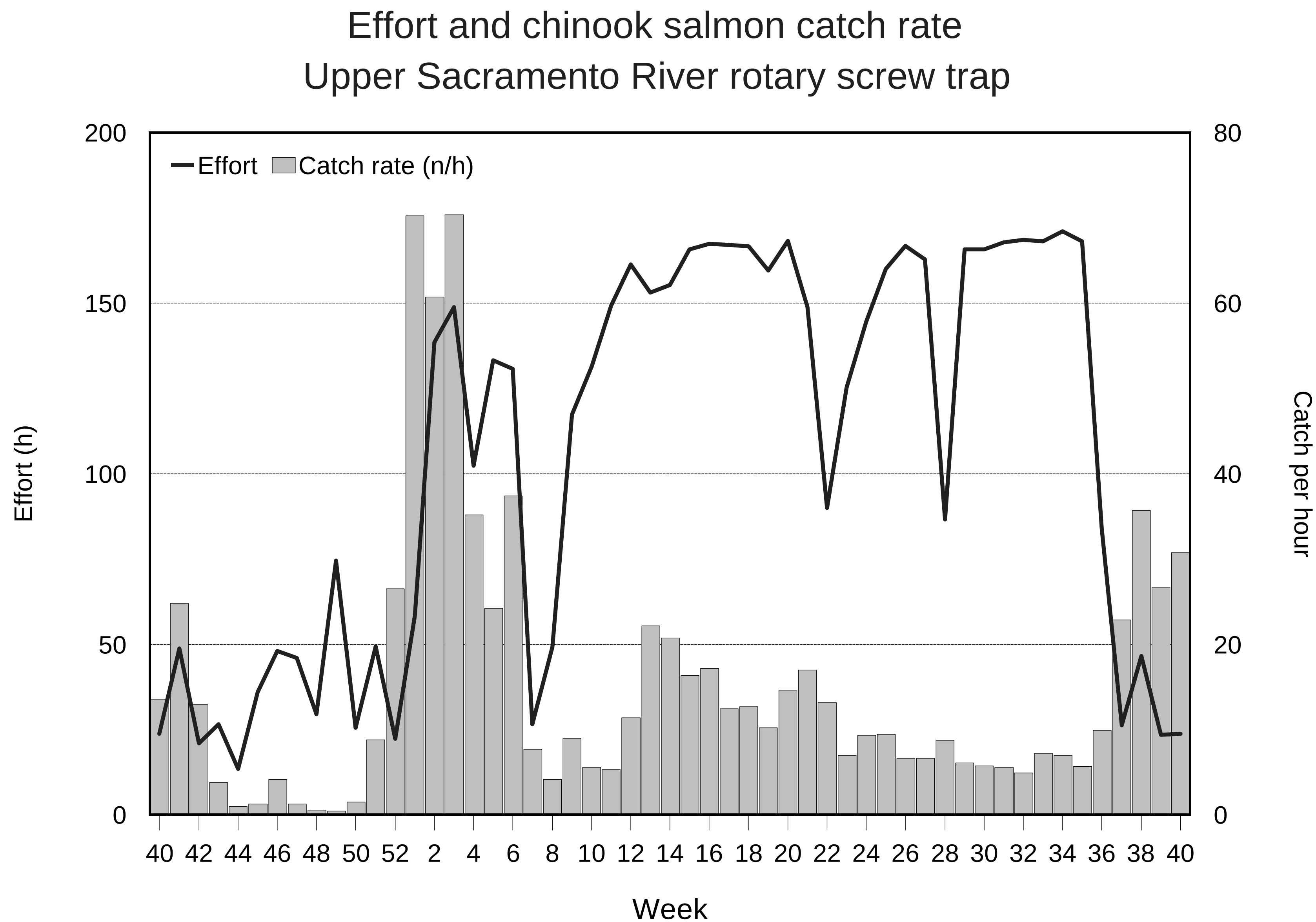


Figure 35. Weekly catch rate of chinook salmon and hours fished by rotary screw trap in the upper Sacramento River, 1 October 1998 - 30 September 1999.

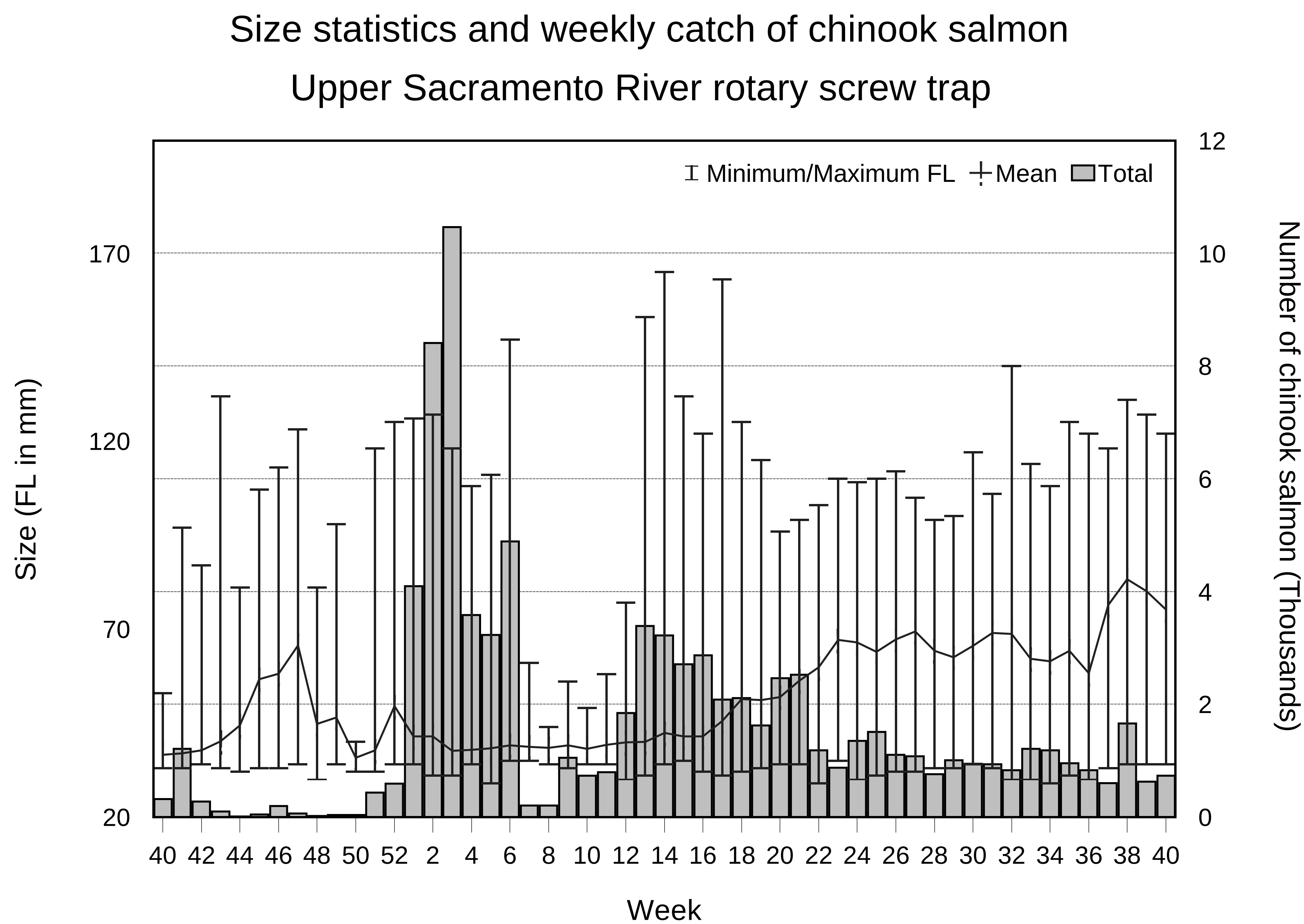


Figure 36. Weekly catch and size statistics of chinook salmon caught by rotary screw trap in the upper Sacramento River, 1 October 1998 - 30 September, 1999.

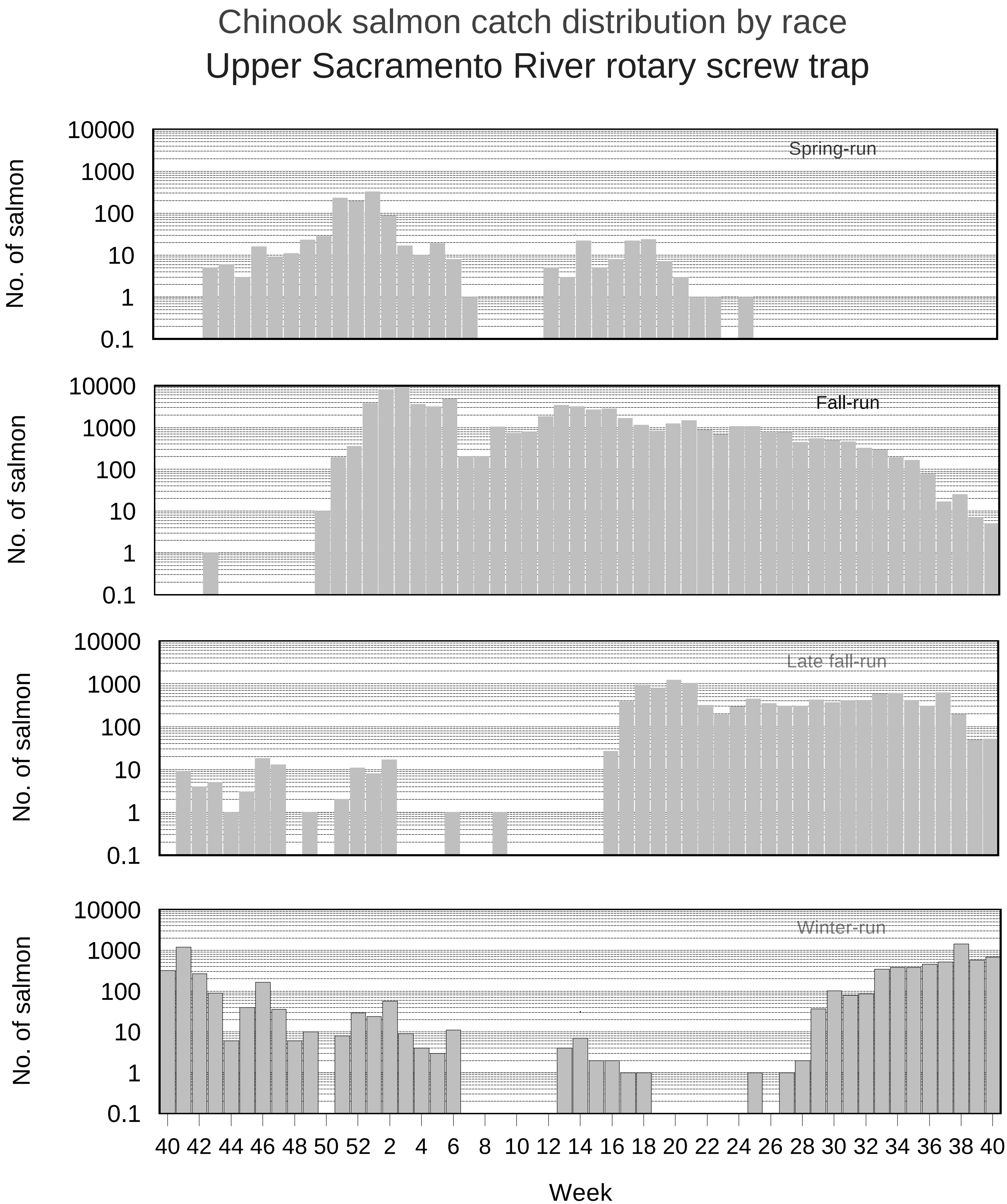


Figure 37. Catch distribution of chinook salmon races collected by rotary screw trap in the upper Sacramento River, 1 October, 1998 - 30 September, 1999.

Chinook salmon size distribution by race
Upper Sacramento River rotary screw trap

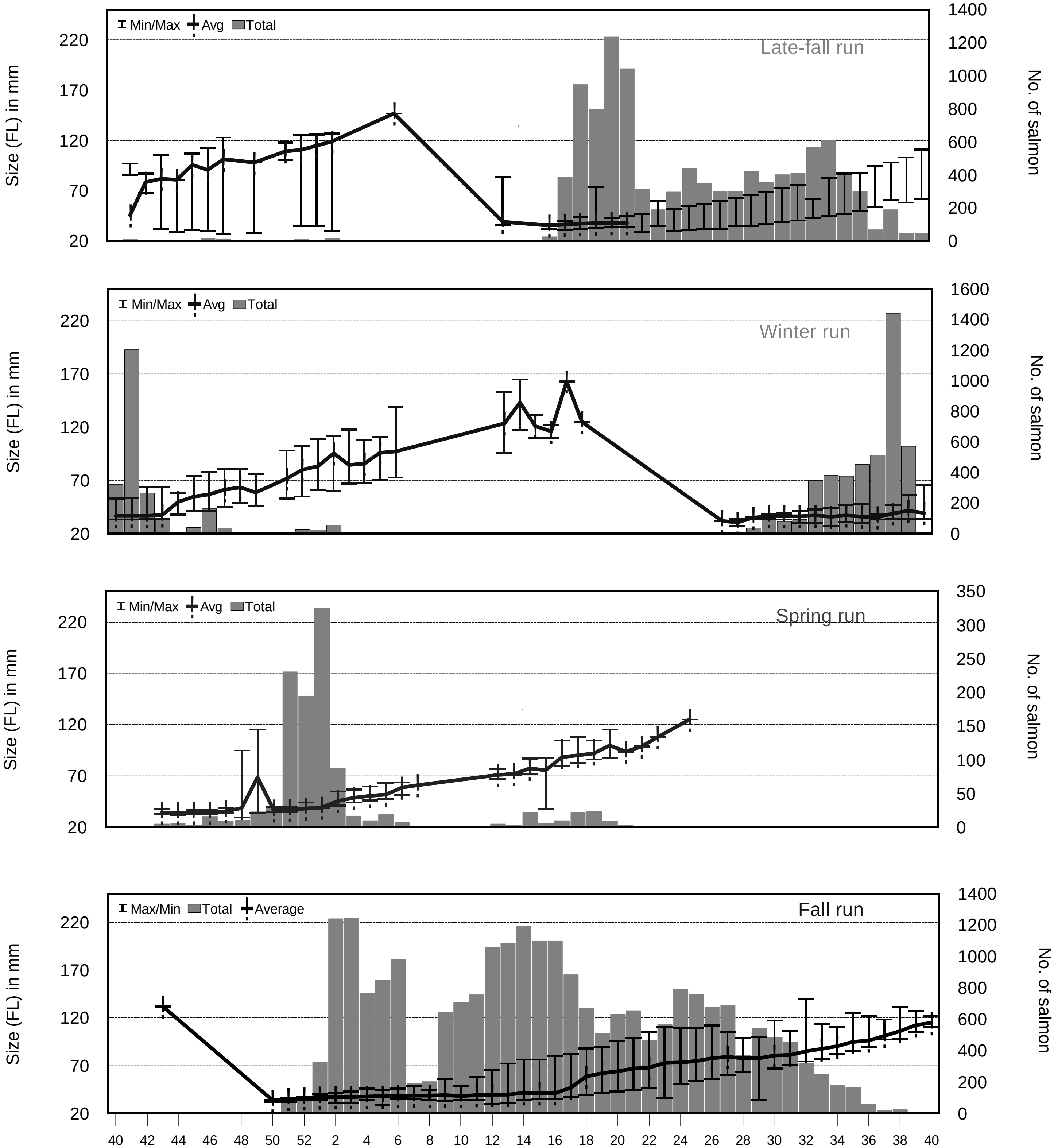


Figure 38. Weekly catch and size statistics for the four races of chinook salmon collected by rotary screw trap in the upper Sacramento River, 1 October, 1998 - 30 September, 1999.

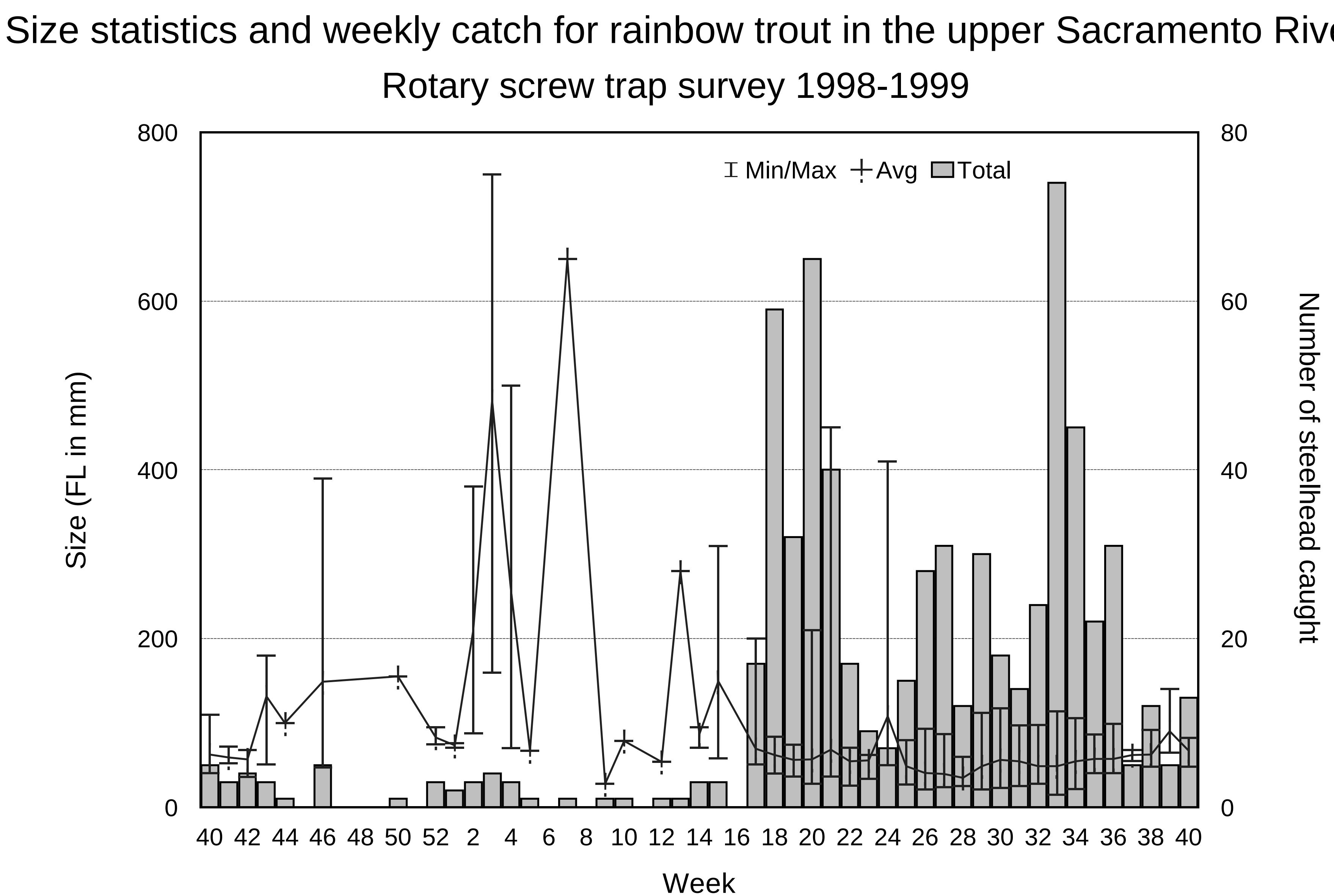


Figure 39. Weekly number and the mean size (minimum and maximum FL) of rainbow trout caught by rotary screw trap in the upper Sacramento River, 1 October 1998 - 30 September 1999.

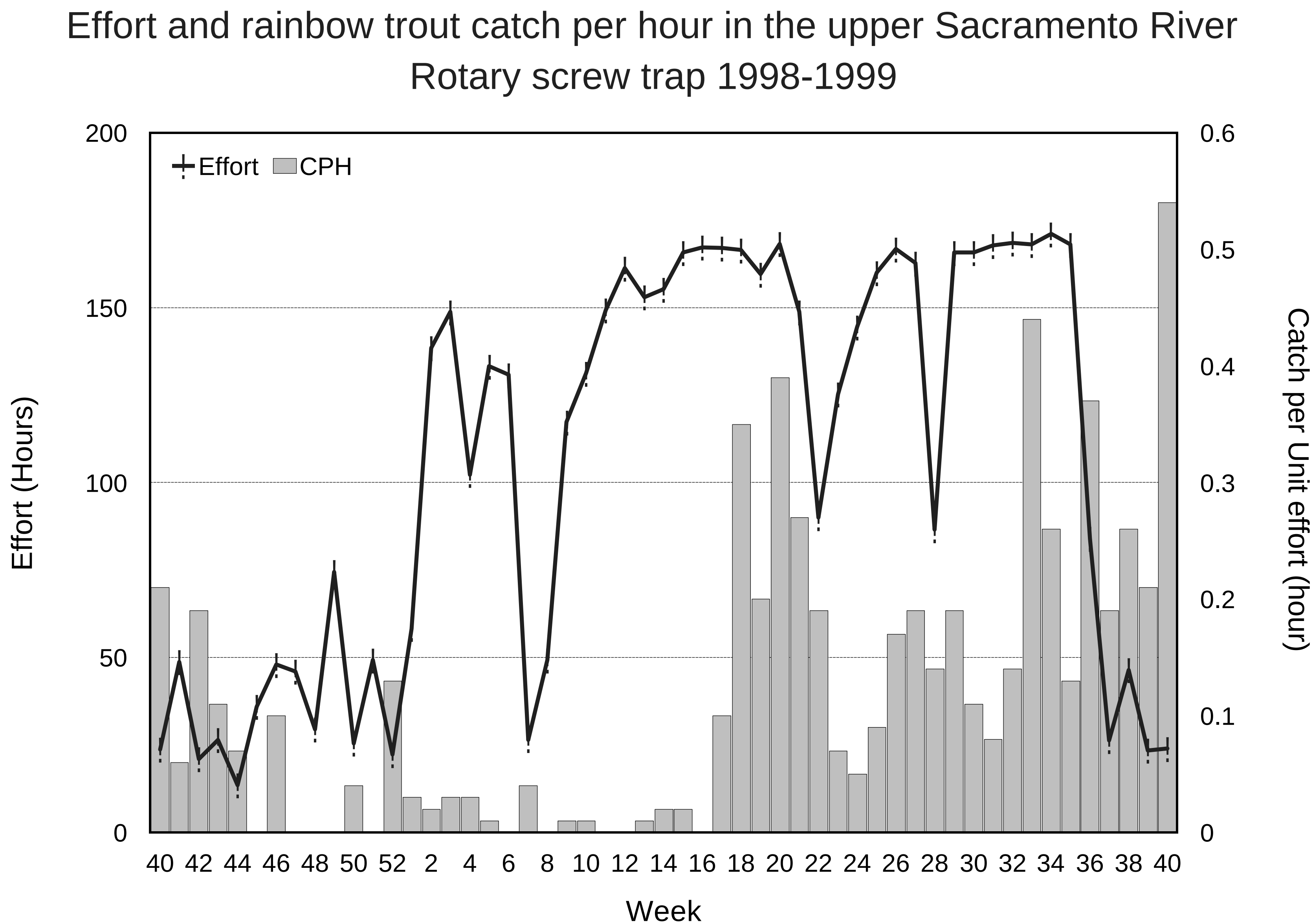


Figure 40. Weekly catch per hour of rainbow trout and hours fished by rotary screw trap in the upper Sacramento River, 1 October, 1998 - 30 September, 1999.

APPENDIX I

Upper Sacramento River Habitat Type Distribution List

Appendix I. Habitat distribution from river mile 271 near the mouth of Battle Creek upstream to Keswick Dam at river mile 302, Sacramento River *(table continues on next page).*

RIVER		LOCATION	HABITAT	
Reach	Site ID #		Zone	Type
3[1/]	1	RM 271	Bar Complex	Run
	2		Bar Complex	Run
	3		Bar Complex	Riffle
	4		Bar Complex	Riffle
	5	Barge Hole/Battle creek	Bar Complex	Pool
	6		Bar Complex	Riffle
	7		Bar Complex	Glide
	8	RM 272	Flatwater	Glide
	9	RM 273	Bar Complex	Run
	10	Cottonwood Creek	Bar Complex	Riffle
	11	RM 274/Redding Island	Flatwater	Glide
	12	RM 275	Flatwater	Run
	13	RM 276	Flatwater	Riffle
	14	Balls Ferry Bridge Crossing	Flatwater	Glide
	15	RM 277	Flatwater	Pool
	16	Ash Creek	Flatwater	Run
	17	Hickman Riffle	Flatwater	Riffle
	18	Bear Creek	Flatwater	Glide
	19	RM 278	Flatwater	Run
	20		Bar Complex	Run
	21		Bar Complex	Riffle
	22		Bar Complex	Run
	23		Bar Complex	Riffle
	24		Flatwater	Glide
	25		Flatwater	Run
	26	RM 279/Power Line Riffle	Flatwater	Riffle
	27	RM 279	Flatwater	Glide
	28	Haas Hole	Bar Complex	Pool
	29	RM 280/Cow Creek	Bar Complex	Run
2[2/]	30	RM 280	Bar Complex	Riffle
	31		Bar Complex	Run

Appendix I. *(table continues on next page).*

RIVER		LOCATION	HABITAT	
Reach	Site ID #		Zone	Type
2[2/]	32		Bar Complex	Riffle
	33	RM 281/Deschutes Road/Stillwater Creek	Flatwater	Glide
	34	RM 281	Bar Complex	Run
	35	Hawes Riffle	Off-Channel Area	---
	36		Bar Complex	Riffle
	37	RM 282	Off-channel Area	---
	38		Bar Complex	Glide
	39		Flatwater	Glide
	40		Flatwater	Run
	41		Bar Complex	Riffle
	42		Flatwater	Pool
	43		Flatwater	Glide
	44	RM 283	Flatwater	Pool
	45	RM 284/Churn Creek/North Street Bridge	Flatwater	Glide
	46	RM 285/HWY 5 Crossing	Flatwater	Run
	47		Flatwater	Pool
	48		Flatwater	Glide
	49		Flatwater	Run
	50	Lower Plywood Riffle	Flatwater	Riffle
	51	RM 286	Flatwater	Glide
	52	Upper Plywood Riffle	Flatwater	Run
	53		Bar Complex	Riffle
	54	RM 287	Flatwater	Run
	55		Flatwater	Riffle
	56		Flatwater	Glide
	57		Flatwater	Glide
	58		Flatwater	Run
	59		Bar Complex	Riffle
	60		Bar Complex	Riffle
	61		Secondary Channel	Riffle
	62		Bar Complex	Run
	63		Bar Complex	Run
	64	Joe Deering Riffle/RM 288	Bar Complex	Riffle

Appendix I. *(table continues on next page)*

RIVER		LOCATION	HABITAT	
Reach	Site ID #		Zone	Type
2[2/]	65		Off-Channel Area	---
	66		Bar Complex	Riffle
	67		Flatwater	Glide
	68		Bar Complex	Riffle
	69		Bar Complex	Riffle
	70		Bar Complex	Glide
	71	RM 289	Off-Channel Area	---
	72		Off-Channel Area	---
	73		Bar Complex	Run
	74		Off-Channel Area	---
	75		Bar Complex	Riffle
	76		Secondary Channel	Riffle
	77		Secondary Channel	Pool
	78		Secondary Channel	Riffle
	79		Off-Channel Area	---
	80	RM 289/Olney Creek	Secondary Channel	Pool
	81	RM 291	Bar Complex	Glide
	82		Secondary Channel	Run
	83		Secondary Channel	Riffle
	84		Secondary Channel	Riffle
	85		Bar Complex	Run
	86		Bar Complex	Riffle
	87		Bar Complex	Glide
	88		Bar Complex	Riffle
	89		Off-Channel Area	---
	90		Flatwater	Glide
	91		Flatwater	Run
	92		Secondary Channel	Riffle
	93		Secondary Channel	Run
	94		Secondary Channel	Riffle
	95		Off-Channel Area	---
	96		Secondary Channel	Run
	97	Tobiasson Riffle/RM 291	Secondary Channel	Riffle

Appendix I. *(table continues on next page)*

RIVER		LOCATION	HABITAT	
Reach	Site ID #		Zone	Type
2[2/]	98	RM 291	Bar Complex	Riffle
	99	RM 292	Flatwater	Glide
	100	South Bonny View Road Crossing	Flatwater	Run
	101		Bar Complex	Pool
	102		Bar Complex	Riffle
	103	Golf Course Riffle	Bar Complex	Riffle
	104	RM 293	Bar Complex	Run
	105		Flatwater	Run
	106	Wyndom Riffle	Bar Complex	Run
	107	RM 294	Off-Channel Area	---
	108		Bar Complex	Riffle
	109		Flatwater	Glide
	110		Bar Complex	Glide
	111		Bar Complex	Run
	112	Rm 295/Cypress Avenue Bridge	Bar Complex	Riffle
	113	RM 295	Bar Complex	Glide
	114		Off-Channel Area	---
	115		Bar Complex	Run
	116	Kutras Lake	Off-Channel Area	---
	117		Bar Complex	Riffle
	118		Bar Complex	Pool
	119		Bar Complex	Riffle
	120		Flatwater	Glide
	121	Kutras Island/RM 296	Flatwater	Run
	122		Flatwater	Run
	123	East Island	Bar Complex	Riffle
	124	Turtle Bay East	Bar Complex	Riffle
	125	West Island	Bar Complex	Riffle
	126		Off-Channel Area	---
	127		Off-Channel Area	---
	128		Secondary Channel	Riffle
	129	HWY 299/Turtle Bay West	Bar Complex	Glide
	130		Bar Complex	Pool

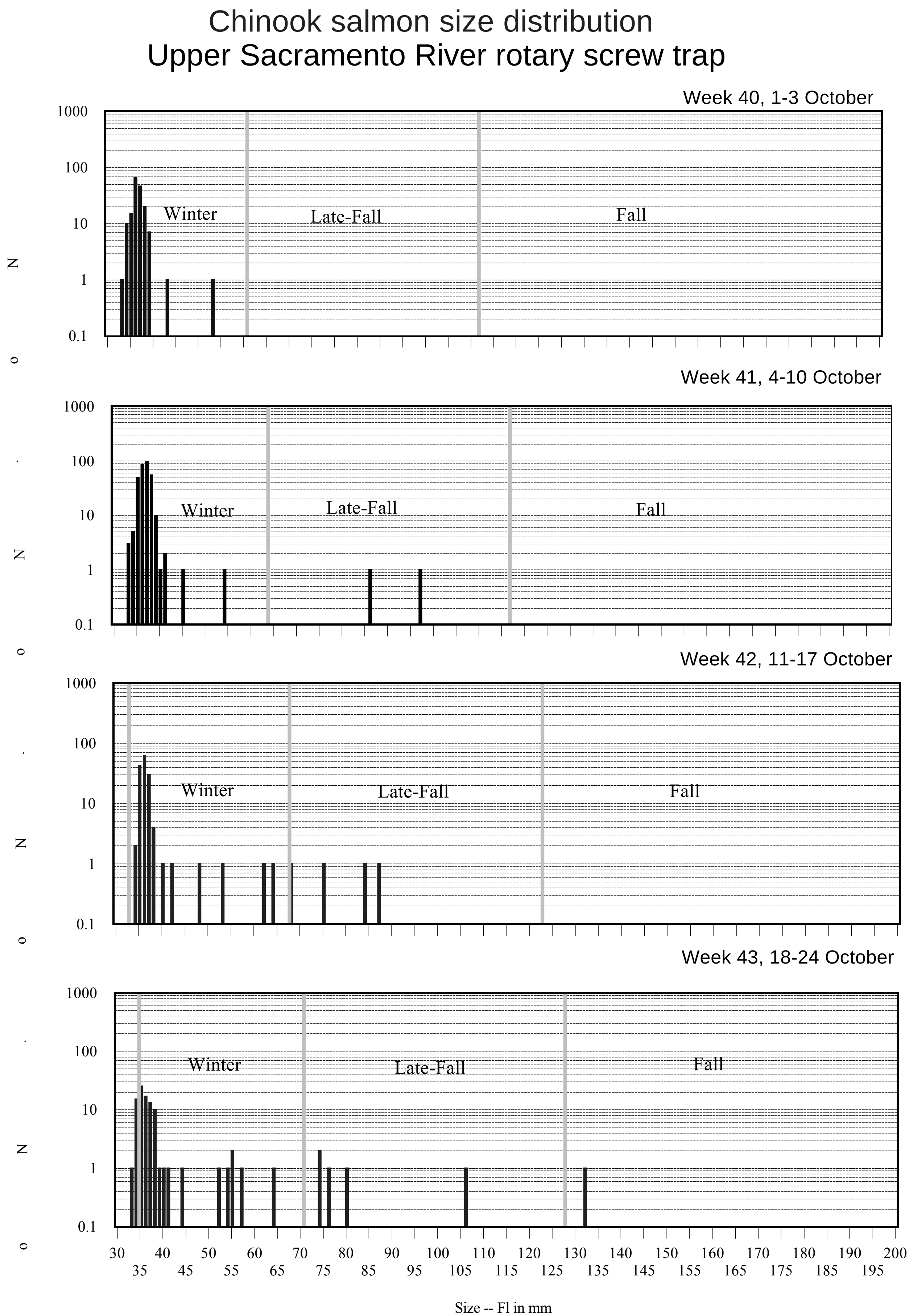
Appendix I. *(table ends)*

RIVER		LOCATION	HABITAT	
Reach	Site ID #		Zone	Type
2[2/]	131		Bar Complex	Run
	132	RM 297	Bar Complex	Riffle
	133		Flatwater	Glide
	134		Flatwater	Run
	135		Flatwater	Riffle
	136	Rm 298	Flatwater	Glide
	137		Flatwater	Run
	138		Flatwater	Riffle
1[3/]	139	RM 299/Lake Redding	Flatwater	Pool
	140		Flatwater	Glide
	141	RM 300		Run
	142			Pool
	143	Keswick Dam/RM 301		Run

1/ Reach 3: River Miles 271.0 to 280.2, Habitat unit numbers 1 through 29
2/ Reach 2: River Miles 280.2 to298.5, Habitat unit numbers 30 through 138
3/ Reach 1: River Miles 298.5 to 302.0, Habitat unit numbers 139 through 143

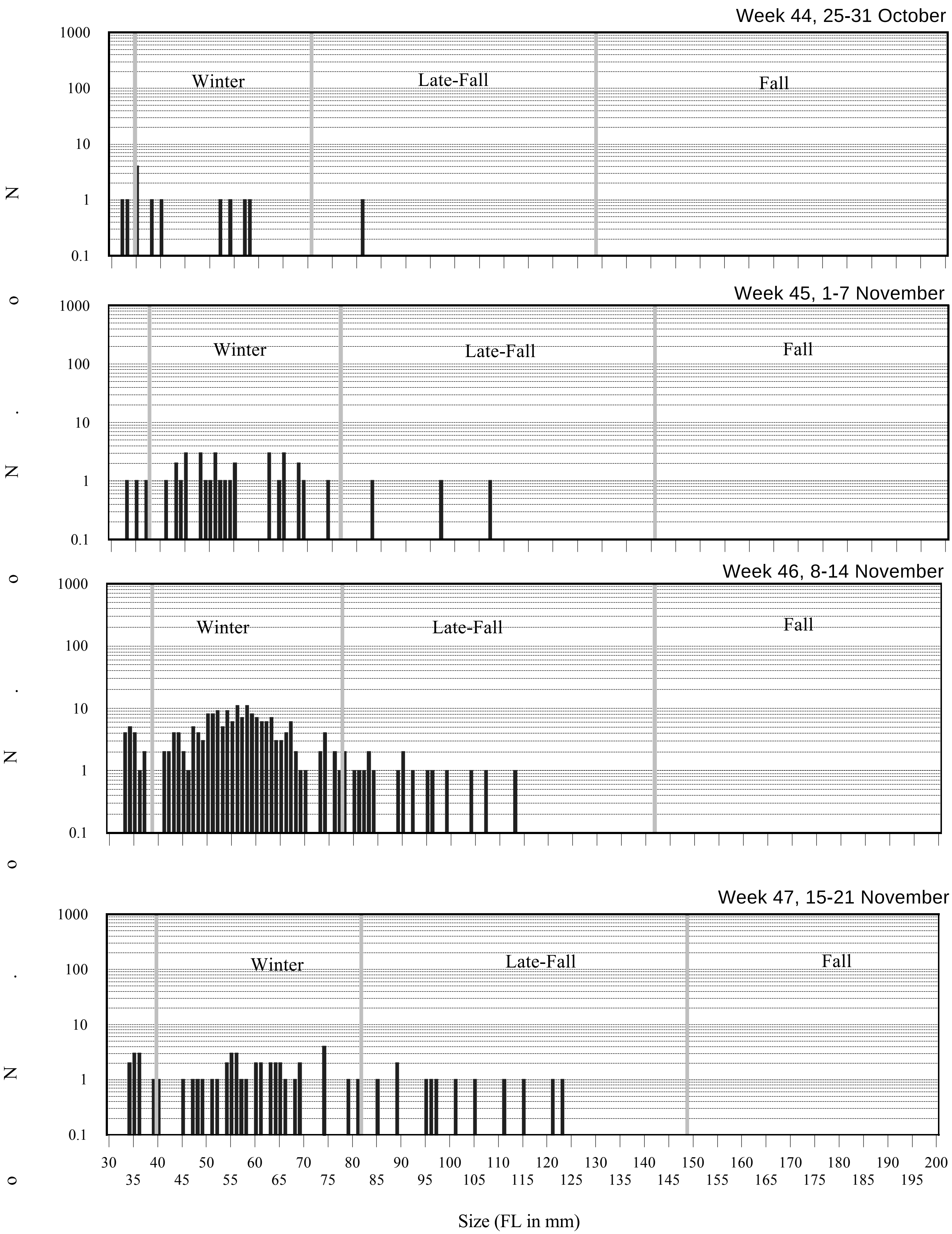
APPENDIX II

Rotary screw trap catch weekly length distribution



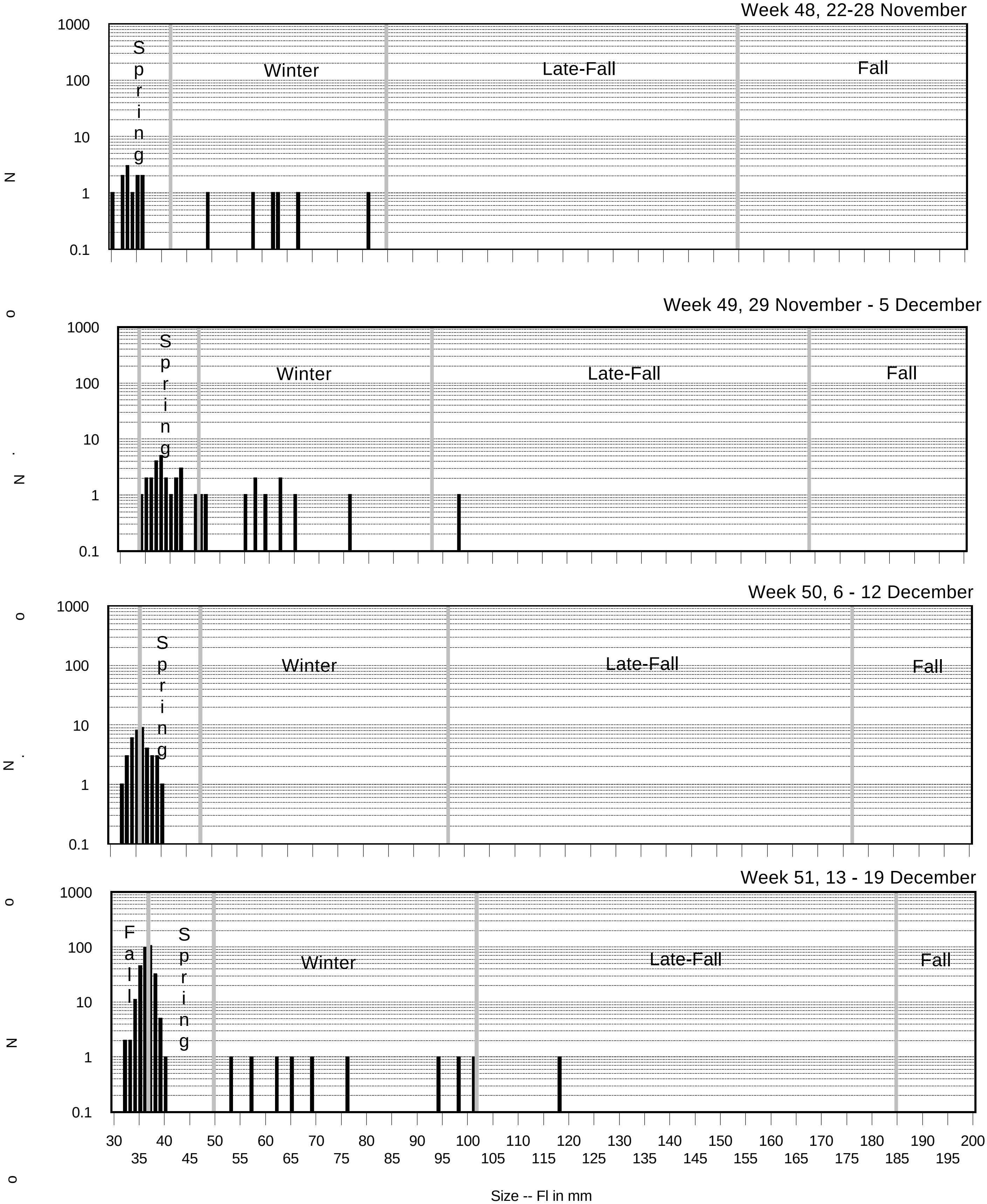
II-1. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 1 October, 1998 - 24 October, 1998.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap



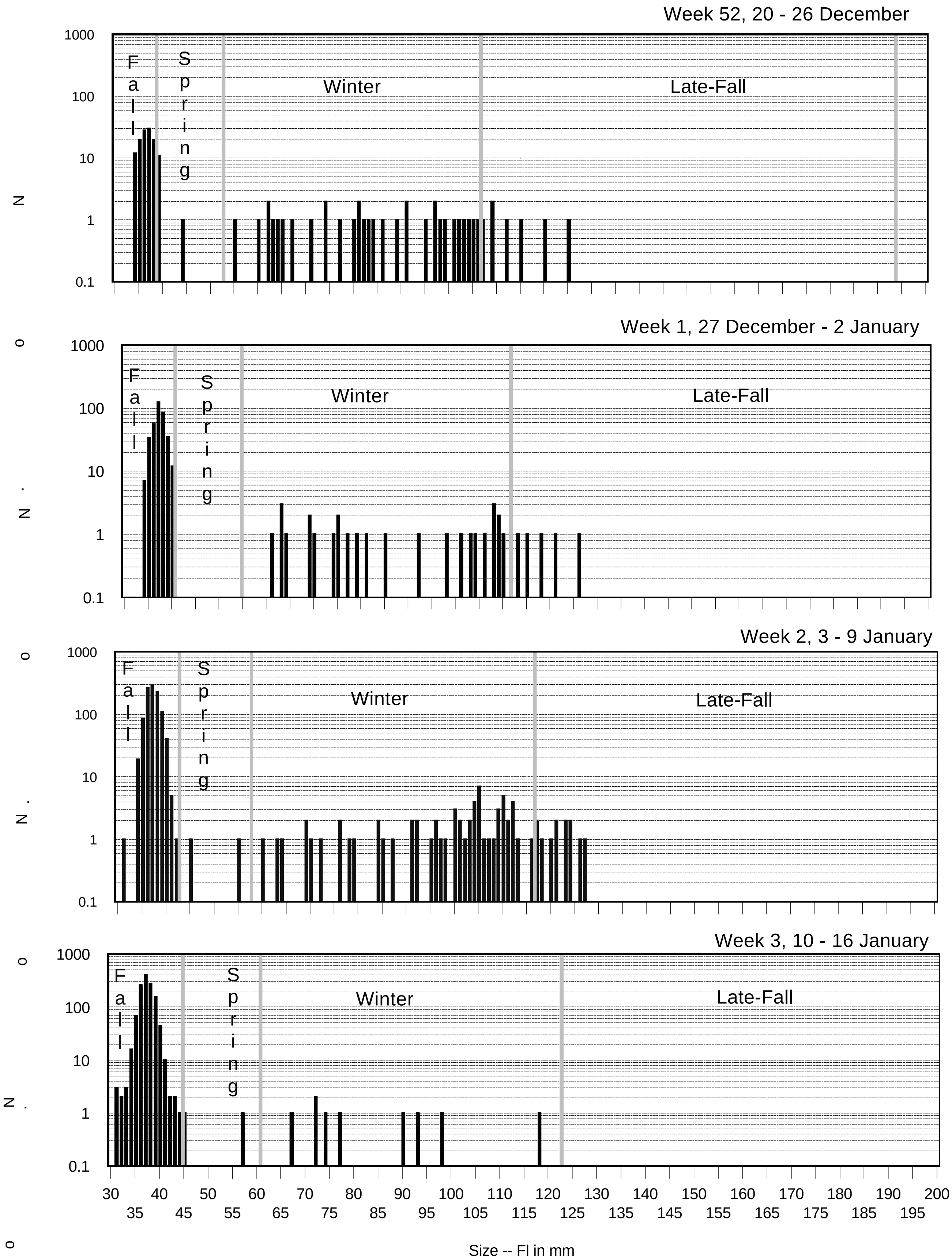
II-2. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 25 October, 1998 - 21 November, 1998.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap



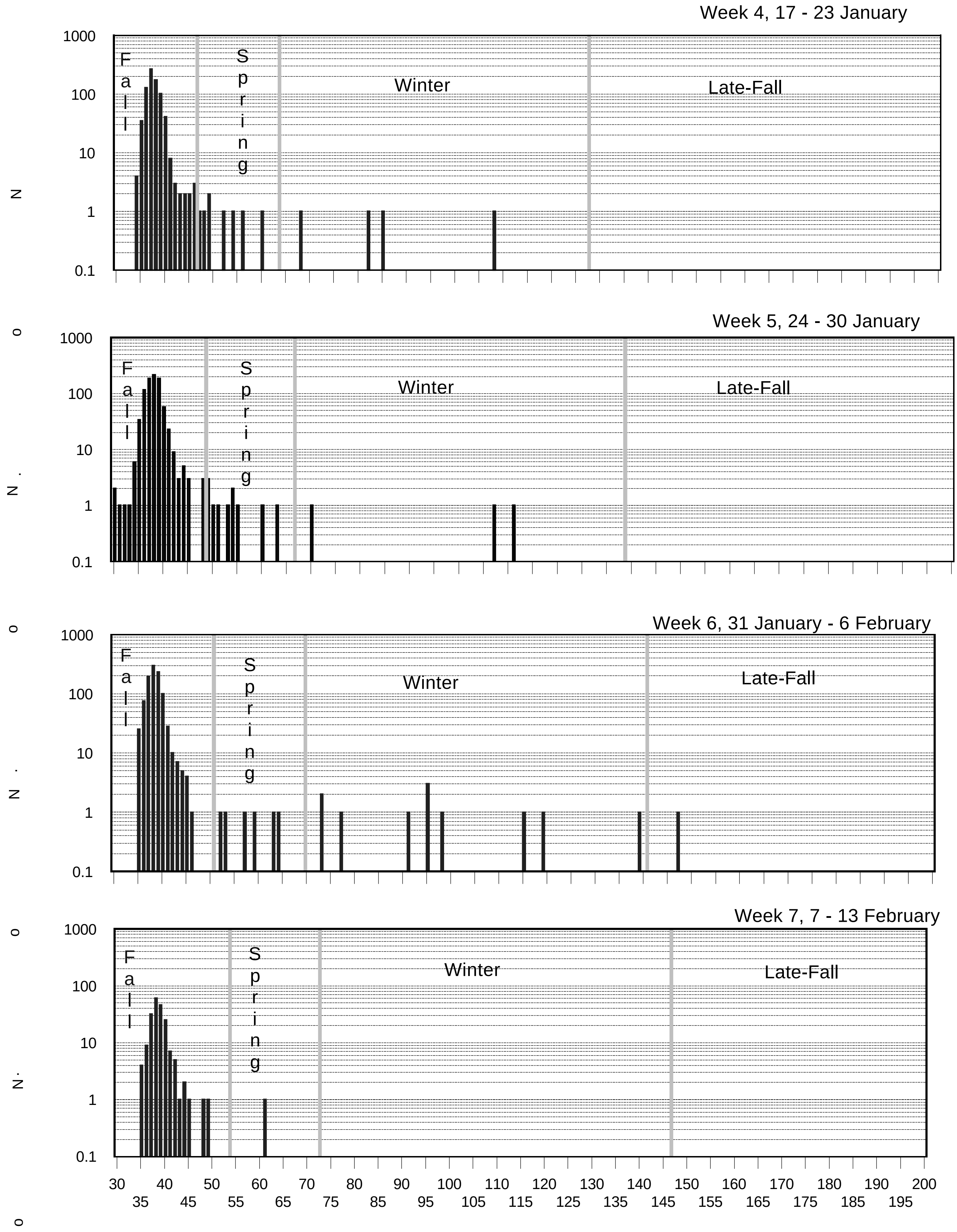
II-3. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 22 November, 1998 - 19 December, 1998.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap



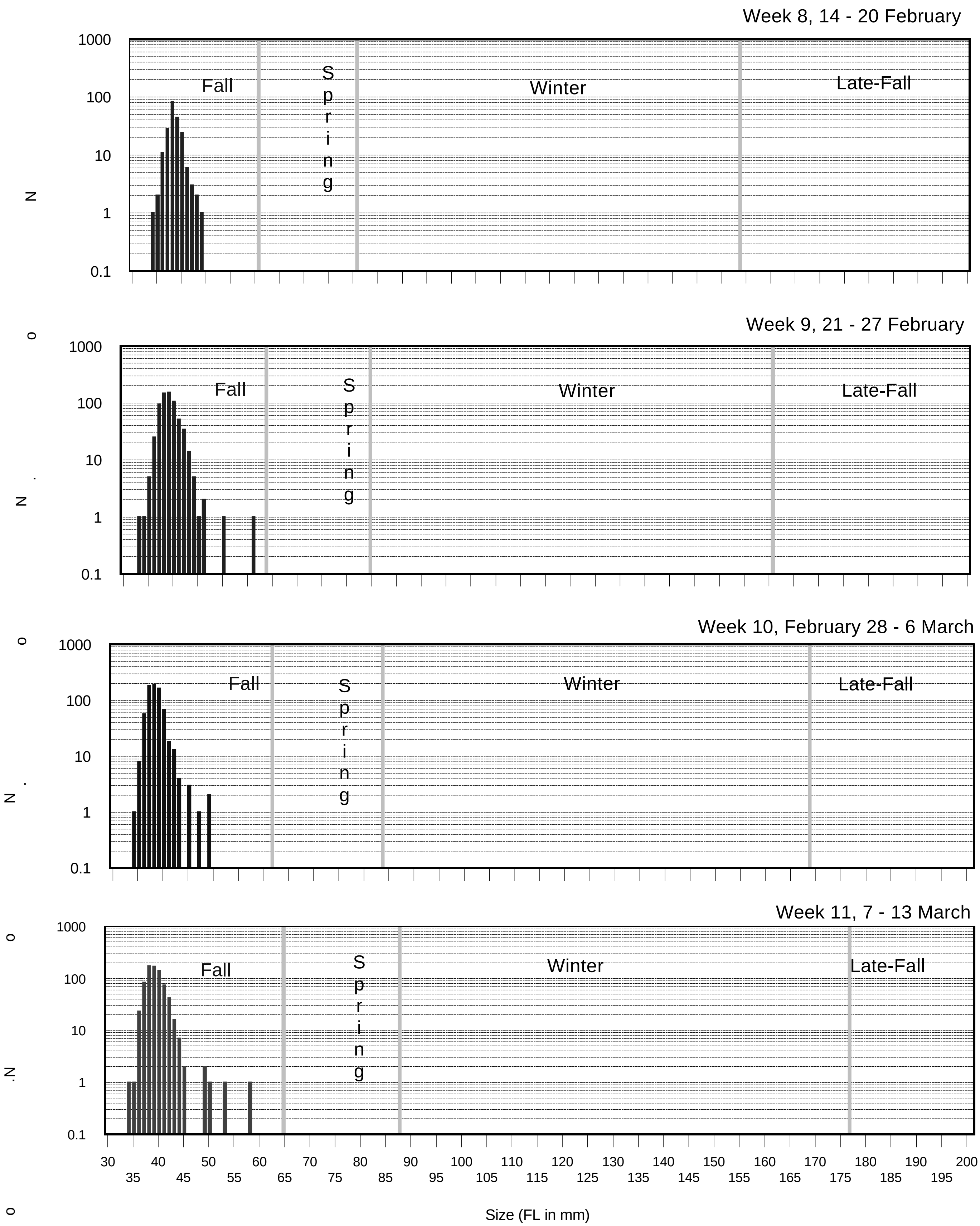
II-4. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 20 December, 1998 - 16 January, 1999.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap



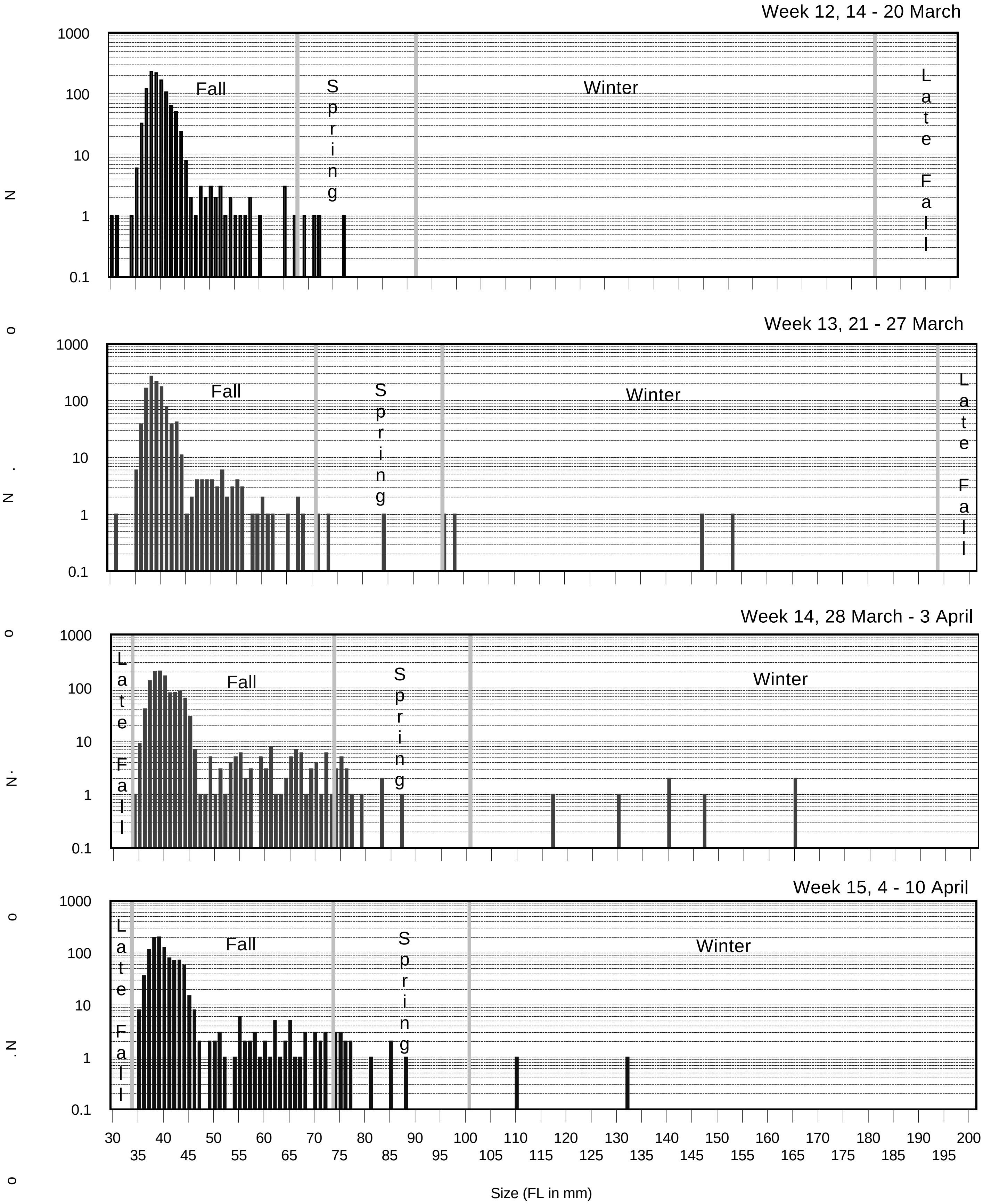
II-5. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 17 January, 1999 - 13 February, 1999.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap

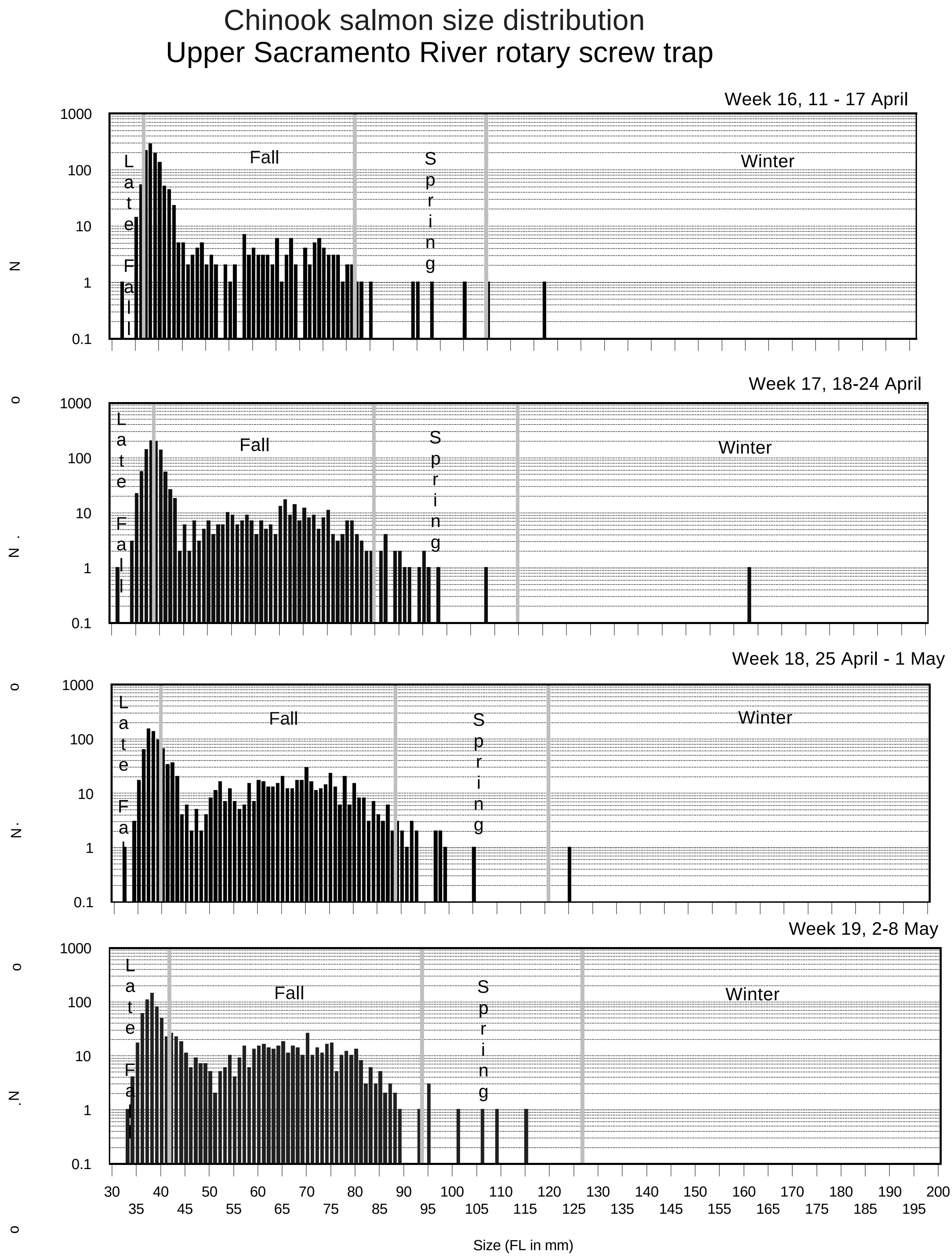


II-6. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 14 February, 1999 - 13 March, 1999.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap

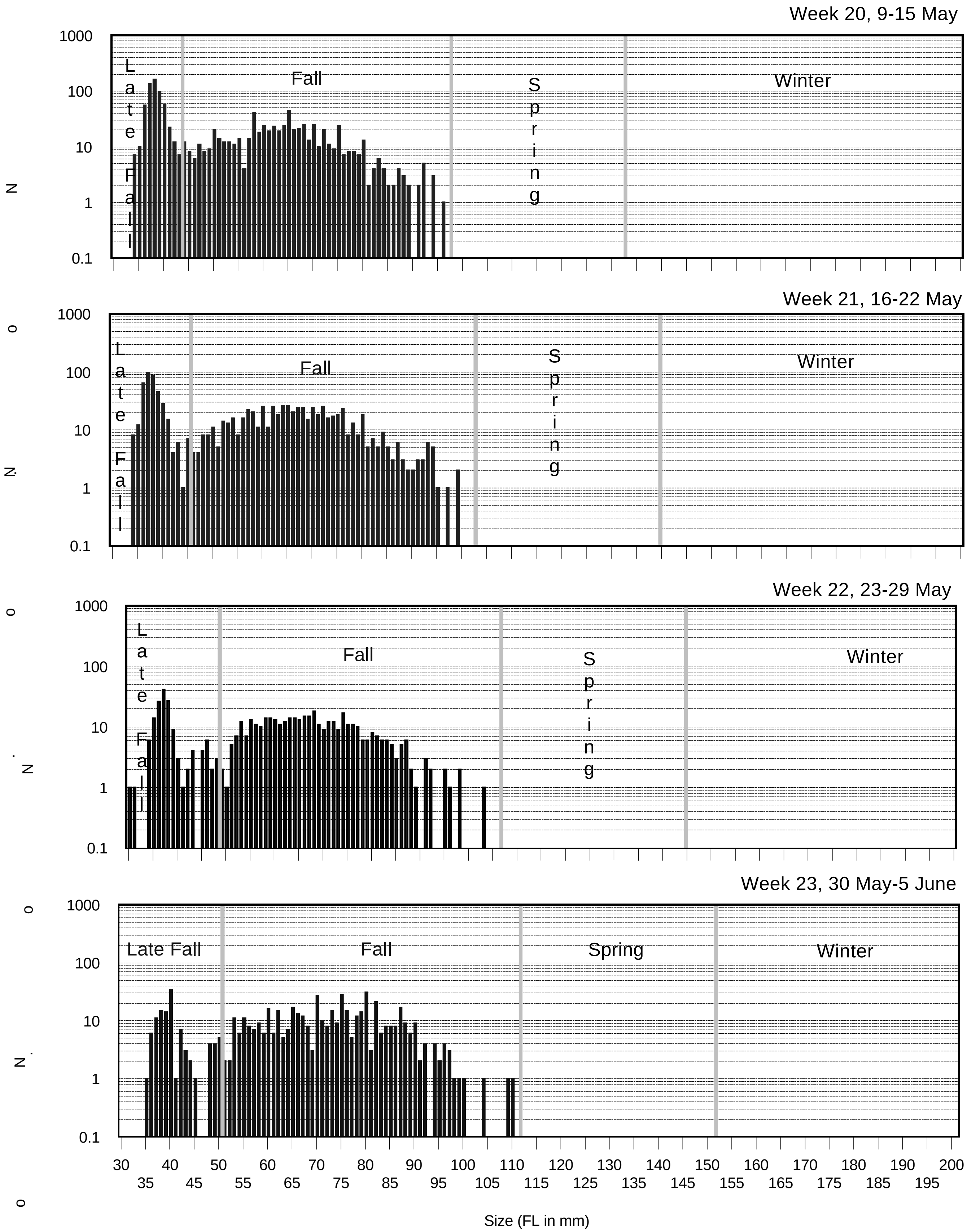


II-7. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 14 March, 1999 - 10 April, 1999.

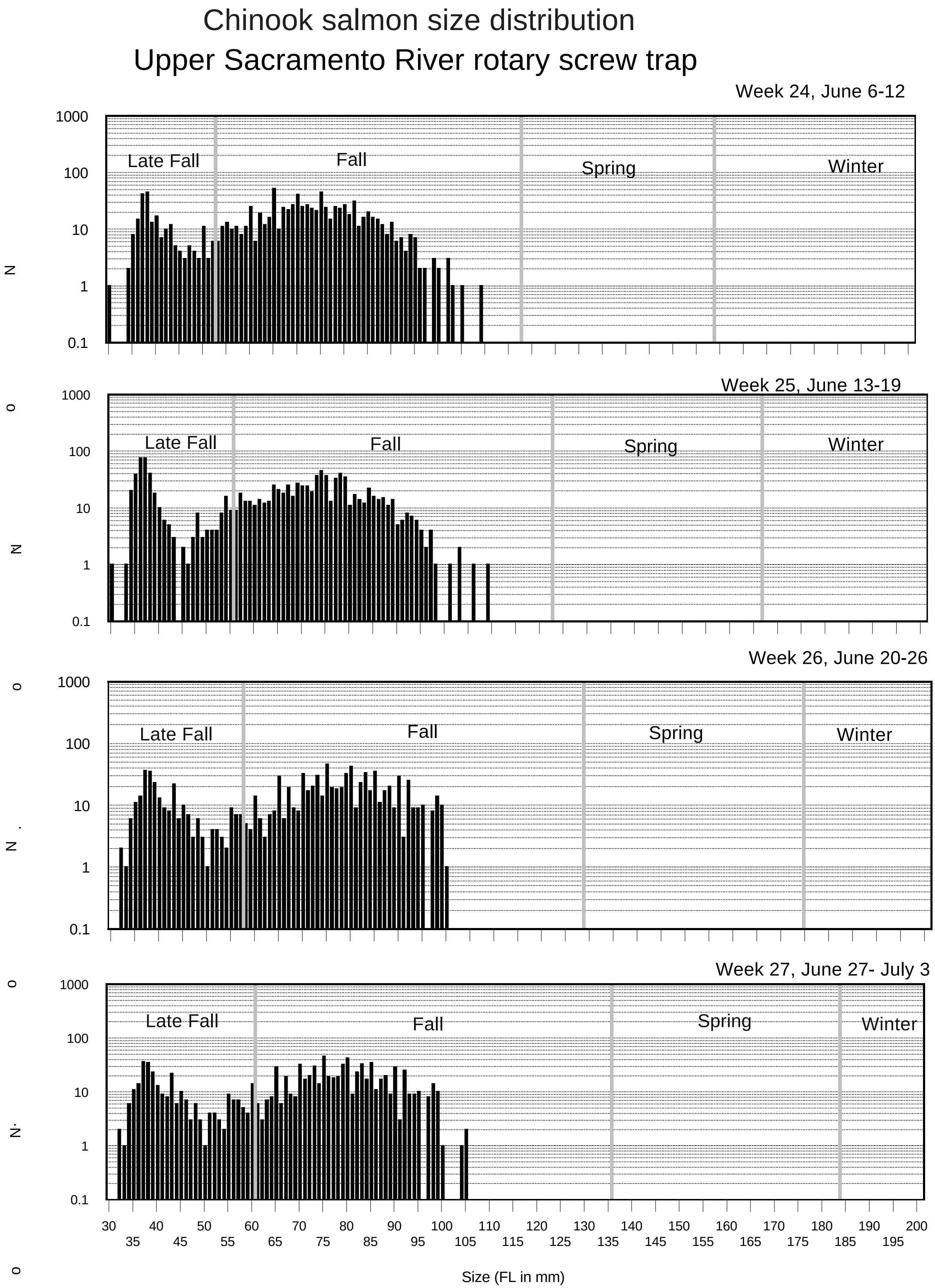


II-8. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 11 April, 1999 - 8 May, 1999.

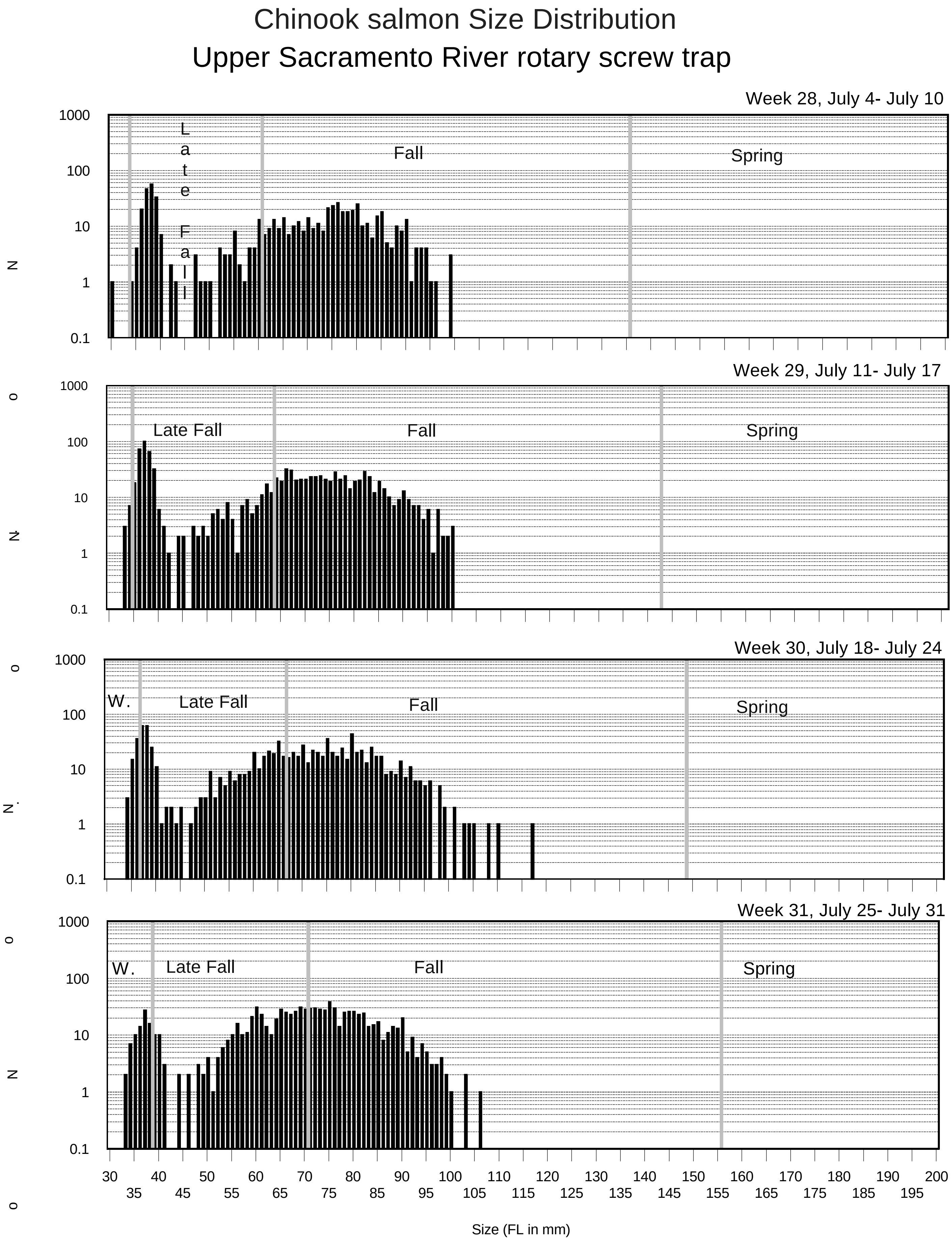
Chinook salmon size distribution
Upper Sacramento River rotary screw trap



II-9. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 9 May, 1999 - 5 June, 1999.

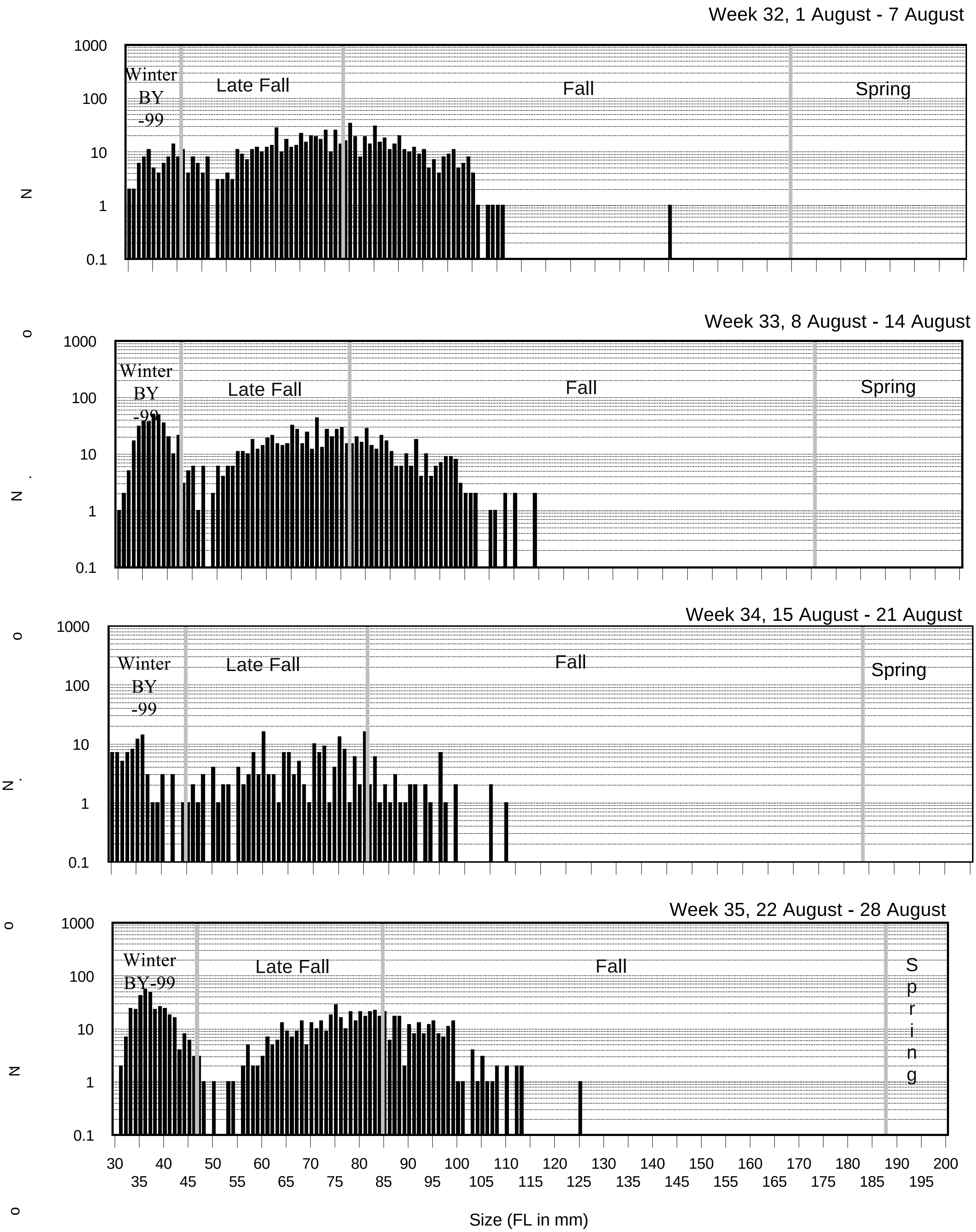


II-10. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 6 June, 1999 - 3 July, 1999.



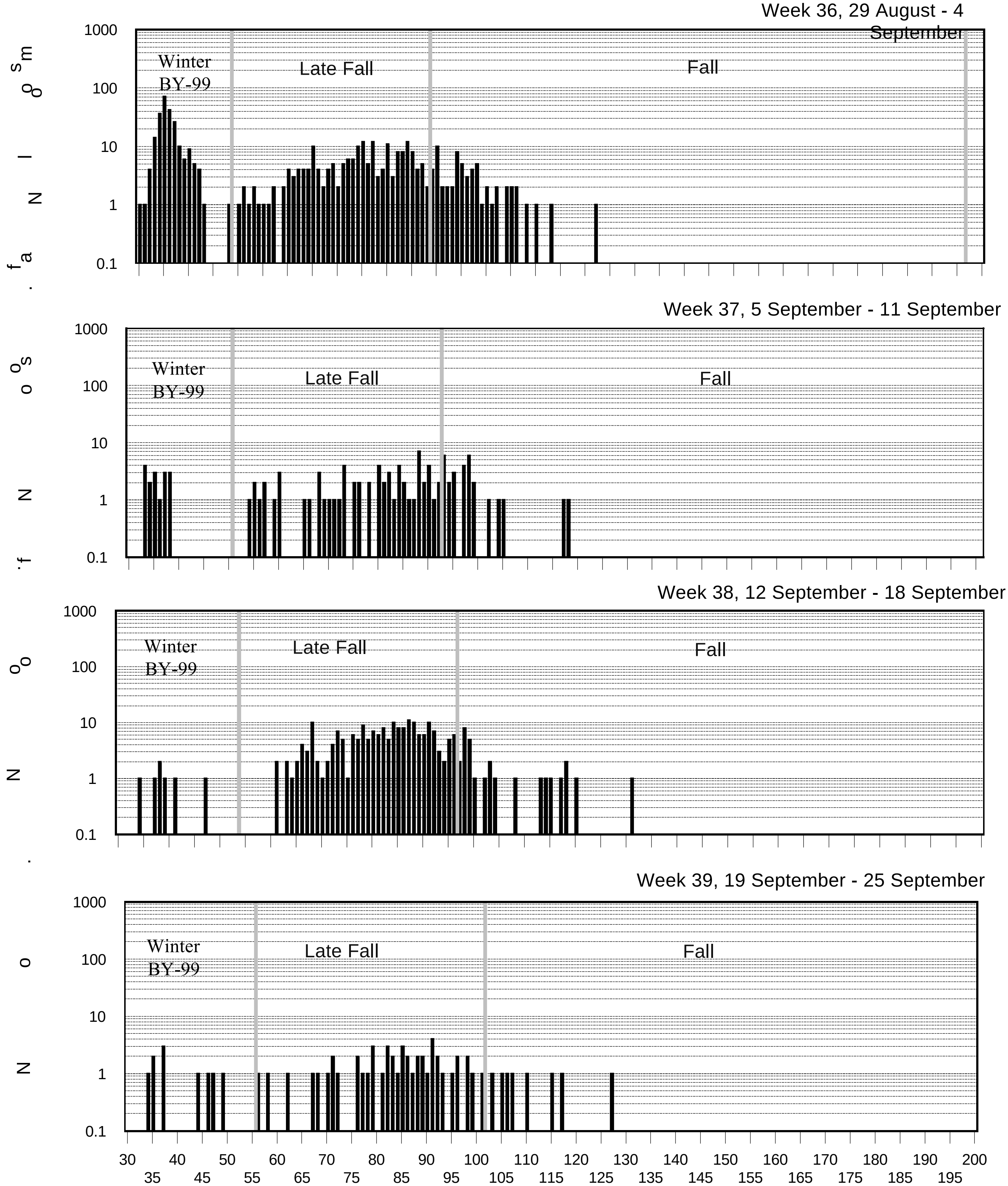
II-11. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 4 July, 1999 - 31 July, 1999.

Chinook salmon size distribution
Upper Sacramento River rotary screw trap



II-12. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 1 August, 1999 - 28 August, 1999.

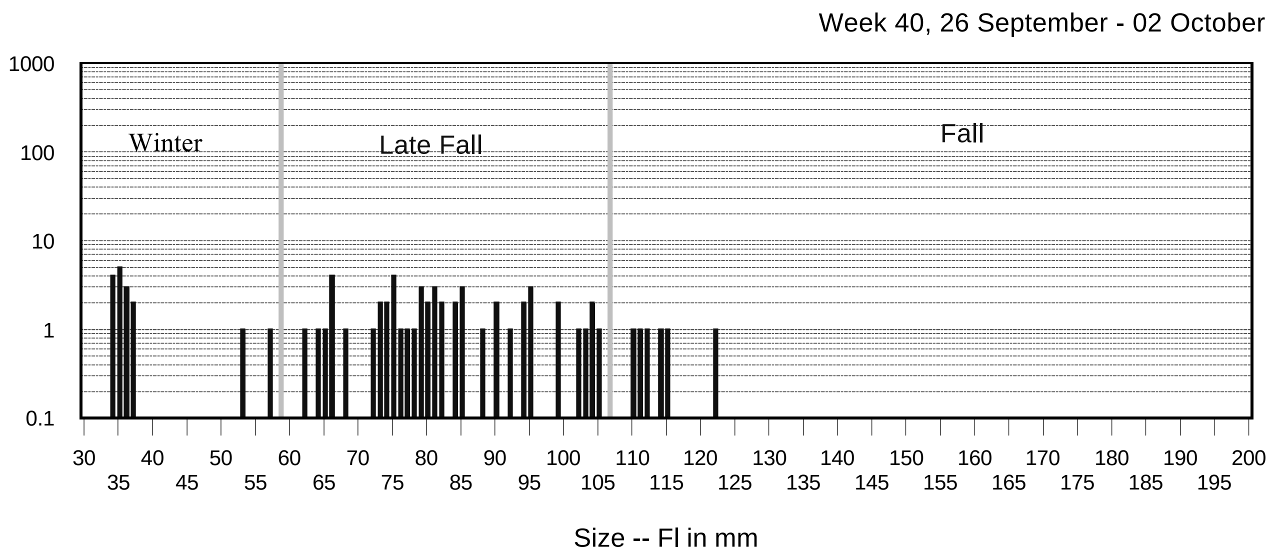
Chinook salmon size distribution
Upper Sacramento River rotary screw trap



II-13. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 29 August, 1999 - 25 September, 1999.

Chinook salmon size distribution

Upper Sacramento River rotary screw trap



II-14. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 26 September, 1999 - 2 October, 1999.

APPENDIX III

Fall-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Water and Aquatic Habitat Conservation Branch
Stream Evaluation Program

Upper Sacramento River
Fall-Run Chinook Salmon Escapement Survey
September - December 1998[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

May 1999

1/ This work was supported by funding provided by U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report 99-2.

SUMMARY

A fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during fall-winter 1998 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the fourth consecutive year a fall-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider *et. al.* 1997; Snider *et. al.* 1998a; and Snider *et. al.* 1998b).

The survey was conducted from 28 September through 17 December 1998. It included 25.5 miles of the Sacramento River, from Cottonwood Creek to Anderson-Cottonwood Irrigation District (ACID) dam located just 3.5 miles downstream of Keswick Dam (the upstream limit to migration). Flows averaged 8,400 cubic feet per second (cfs) during survey week 1 (28 September - 1 October 1998); decreased to 6,000 cfs in weeks 4, 5, and 6 (19 October - 5 November); and then gradually increased to 23,400 cfs during week 11 (7 - 11 December). Mean weekly water temperature ranged from 51^{o} F during weeks 9 and 10 (23 November - 3 December) to 55^{o} F during weeks 2, 3, and 4 (5 - 22 October).

We examined 3,726 fall-run carcasses (fresh and decayed) of which 1,111 fresh carcasses were measured, sexed, and aged. Based upon this sample, 86% of the population were adult salmon (>2-years old) and 14% were grilse (2-years old); 31% were adult males, 55% were adult females, 6% were male grilse and 7% were female grilse (38% male; 62% female). Carcasses were observed during every week of the survey. Peak carcass recovery occurred during weeks 4 through 7 (19 October -13 November) which indicated that peak spawning likely occurred from 5 - 31 October 1997.

We examined 678 females for egg retention. Of these, 647 (96%) had completely spawned; 9 (1%) still contained a substantial number of eggs; and 22 (3%) were unspawned.

Two known (adipose clipped) hatchery produced fall-run spawners were observed. The minimum estimated proportion of hatchery produced spawners was 0.4% adult and 2.7% grilse.

The spawner population was estimated using two different mark-recapture models, the Schaefer and Jolly-Seber models. Per the Schaefer model, 893 fresh adult carcasses were marked and 237 (27%) were subsequently recaptured yielding an escapement estimate of 14,211 total salmon (12,506 adult and 1,705 grilse). Per the Jolly-Seber model, 2,671 fresh and decayed carcasses were marked and 651 (24%) were subsequently recaptured yielding an estimate of 8,559 total salmon (7,532 adults and 1,027 grilse). Both estimates are considerably less than the mean annual fall-run chinook salmon escapement estimate (67,015 grilse and adult) for 1956 through 1998. Escapement estimates from the four most recent annual carcass surveys have ranged from 14,211 to 28,890 with a mean of 23,960 and standard deviation of 5,723.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey on the upper Sacramento River during the fall of 1998 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), PL. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and the DFG have signed a "Cooperative Agreement" by which the FWS will fund DFG to conduct studies to determine flow needs of salmon in the upper Sacramento River.

The primary charge of STEP - to improve understanding of the relationships between salmon and habitat in the upper Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys allows this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Carcass tag-and-recapture surveys have been routinely used to estimate salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for later recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). Fall-run carcass surveys were also conducted in 1995, 1996, and 1997(Snider et. al. 1997; Snider *et. al*. 1998; and Snider *et. al*. 1998) in the upper Sacramento River.

Three models have been used by the DFG to estimate escapement using carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for tributary streams with typically small spawner populations (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in larger Central Valley tributary streams (e.g., Feather and American rivers) since 1973 when it was first used to estimate the Yuba River escapement. Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate

Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.)[1]. Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

Historical Background

The history of efforts to enumerate spawner escapement in the upper Sacramento River has been described by Needham *et. al*. (1943), Fry (1961), Menchen (1970), Snider *et. al*. (1997), and Snider *et. al*. (1998); therefore, it is only briefly reviewed here.

- **1937-1942** Spawner escapement estimates were first made by counting salmon moving through the fish ladder at the ACID dam at river mile (RM) 298.5, near Redding. Annual counts were normally made from April through October or early November, when the dam was installed for irrigation.

- **1943-1945** Salmon were counted at a weir located near Balls Ferry Bridge (RM 278.5).

- **1945-1952** The FWS estimated escapement using "ground level spawning area surveys" (Fry 1961).

- **1950-1955** The DFG estimated spawner escapement by first capturing, tagging, and releasing live salmon at Fremont Weir (RM 82.5), then later recovering them as carcases on the spawning grounds in the upper Sacramento River (Fry 1961).

- **1956-1968** The DFG estimated escapement using carcass counts and aerial redd counts. Experienced personnel estimated the proportion of salmon observed, based upon survey conditions and previous years' experience then expanded the "counts" accordingly.

- **1969-1985** Estimates were based on season-long counts of salmon moving through the fish ladders at Red Bluff Diversion Dam (RBDD) (RM 243). Aerial redd counts were used to determine the proportions of the run spawning above and below RBDD.

- **1986 - present** The DFG's Inland Fisheries Division (IFD) annually estimates fall-

---

[1] Personal communication with Frank Fisher (DFG-Inland Fisheries Division, Red Bluff) and Fred Meyer (DFG -Region 2, Sacramento (retired)).

run escapement using both counts made at RBDD and aerial redd surveys. The dam's gates are now typically open between mid-September and mid-May of the following year improving fish passage but eliminating direct counts at the ladders during up to 8 months of the year. The number of fall-run spawners migrating upstream of RBDD is now based upon an expansion of the number of fish counted when the gates are lowered and fish are forced to migrate through fish ladders passing over the diversion.

When monitoring stocks over a long period, as is the case for the Central Valley salmon escapement surveys, the sampling design should assure the data be collected in a consistent manner and represent the population as a whole (Ney 1993). Lack of these attributes from the Central Valley surveys should not reflect on persons who made population estimates, but on logistic limitations. Annual budgets for temporary employees needed to conduct the escapement surveys were often reduced or eliminated resulting in estimates based on less data. In addition, population estimates were often based on counts made upstream of substantial areas of fall-run spawning activity, e.g., ACID dam, Balls Ferry, and RBDD (Figure 1).

Objectives

The objectives of the upper Sacramento River fall-run chinook salmon escapement survey were:

- To estimate the, in-river, fall-run chinook salmon spawning population for the upper Sacramento River upstream of Cottonwood Creek.

- To determine egg-retention rate, and sex and age composition of fall-run chinook salmon spawning in the upper Sacramento River.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements, and the status of chinook salmon in the upper Sacramento River.

METHODS

The 1998 spawner escapement surveys began immediately following the initial observation of spawning activity and then were conducted weekly from 28 September through 17 December 1998. The 25.5-mile-long stream segment from ACID dam (RM 298.5) downstream to the mouth of Cottonwood Creek (RM 273.0; Figure 1) was divided into four reaches (Table 1). Each reach was surveyed one day per week.

Table 1. Location of survey reaches during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1998.

Reach	Location	River mile (length in miles)
1	ACID Dam to Cypress St. Bridge	298.5-295.0 (3.5)
2	Cypress St. Bridge to Bonnyview Bridge	295.0-292.0 (3.0)
3	Bonnyview Bridge to North St. Bridge	292.0-284.0 (8.0)
4	North St. Bridge to Cottonwood Bridge	284.0-273.0 (11.0)

Surveys were primarily conducted using two boats with two observers per boat. The observers attempted to locate and collect carcasses as each boat traversed the river between the center of the channel and one of the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included: i) those previously tagged, ii) those on shore in a “leathery condition”; iii) those in Reach 4 (the most downstream reach) that would likely wash out of the survey area and never be recovered; and, iv) carcasses in excess of the number that crews could tag during a day. Tagged carcasses were released into running water for recapture to simulate conditions of a naturally dying or dead fish. Data collected included number tagged, number chopped, and number recovered.

All carcasses were also examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from a subsample of the fresh carcasses included gender, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining; as partially spent if a substantial amount of the eggs remained; and unspent if the ovaries appeared nearly full of eggs.

To be consistent with the standard protocol that has been used on most Central Valley streams, escapement estimates were determined using fresh carcass data to calculate a Schaefer model estimate, and both fresh and decayed carcass data to calculate a Jolly-Seber model estimate.

The formulas used to derive the escapement estimates (E) are as follows:

Schaefer model (as described by Taylor 1974): $E=N_{ij}=R_{ij}(T_iC_j/R_iR_j)-T_i$

where:

$N_{i\,j}$= Population size in tagging period *i* recovery period *j*,
R_{ij} = number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
T_i = number of carcasses tagged in the *i*th tagging period,
C_j = number of carcasses recovered and examined in the *j*th recovery period,
R_i = total recaptures of carcasses tagged in the *i*th tagging period, and
R_j = total recaptures of tagged carcasses in the *j*th recovery period.

This model differs from the original in that the number of tags applied after the first week is subtracted from the population estimate to account for sampling with replacement. Schaefer's original model was based on sampling without replacement while in salmon survey conditions, sampling occurs with replacement.

Jolly-Seber model (as described by Boydstun 1994): $E=N_1+D_1+D_2...+D_j$

where:

N_1 = Number of carcasses in the population in period 1, the first period of spawning and dying, and
D_i = number of carcasses that joined the population between periods *i* and *i*+1, with j as the last survey period.

Flow measurements for each day surveyed were obtained from the Keswick gauge operated by the U.S. Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

RESULTS

A total of 3,726 carcasses was observed (Table 2). Mean weekly flow ranged from 6,000 to 8,400 cfs during weeks 1 through 7 (28 September - 13 November); then generally increased; and peaked at 23,400 cfs during week 11 (Table 2, Figure 2). Mean weekly temperature ranged from 51° F during weeks 9 and 10 (23 November - 3 December) up to 55° F during weeks 2, 3, and 4 (5-22 October) (Table 2, Figure 2). Water clarity (Secchi depth) ranged from 5 feet in week 9 (23-25 November) up to 13 feet in weeks 4, 5, and 6 (19 October - 5 November) (Table 2, Figure 2)
.

Temporal Distribution

The temporal distribution of carcasses indicates that spawning occurred from early September through early December. The number of observed carcasses steadily increased from 85 in week 1 (28 September - 1 October) to a peak 677 in week 6 (2-5 November). The highest number of fresh carcasses was observed during week 4 (19-22 October), followed by week 5 then week 6. Correspondingly, the highest numbers of decayed carcasses were observed from week 4 through week 7 (Table 2, Figure 3). These results indicate that most spawning activity occurred between weeks 2 and 5 (5-29 October) and the peak of spawning activity likely occurred during weeks 3, 4 and 5. This observation is based upon an estimated 2 week delay between spawning and mortality, when fresh carcasses become available to be surveyed (Snider and Vyverberg 1995).

Spatial Distribution

The spatial distribution of all observed carcasses was 29% in Reach 1, 36% in Reach 2, 23% in Reach 3, and 12% in Reach 4 (Table 3 and Figure 4).

Size Distribution

A total of 1,111 carcasses was measured (Table 4). Mean adult size was 80.3 cm FL. Size ranged from 43 to 110 cm FL. Male salmon (n=422) averaged 84.6 cm FL (range: 43 - 110 cm FL) (Figure 5). Female salmon (n=689) averaged 77.9 cm FL (range: 49 - 98 cm FL) (Figure 6). The weekly mean size for males ranged from 68.5 to 90.0 cm FL (Figure 7). Weekly mean size for females ranged from 68.8 to 82.6 cm FL (Table 4 and Figure 8).

Length-frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adults (>2-year-old salmon) for each sex (Figures 5 and 6). Male grilse (n=73) were defined as salmon $\leq$ 71 cm FL, and female grilse (n=82) were defined as salmon $\leq$ 67 cm FL (Table 5). Male grilse averaged 62.4 cm FL (range: 43 - 71 cm FL, SD=6.7); male adults (n=349) averaged 89.3 cm FL (range: 72 - 110 cm FL, SD=9.1). Female grilse averaged 61.8 cm FL (range: 49 - 67 cm FL, SD=4.1); female adults (n=607) averaged 79.8 FL (range: 68 - 98 cm FL, SD=6.8).

Table 2. General survey information for the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1998.

Week	Dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]		
					Fresh	Decayed	Total
1	Sep 28 - Oct 1	8,400	11	54	40	45	85
2	Oct 5 - 8	7,800	12	55	79	73	152
3	Oct 13 - 16	6,200	12	55	136	178	314
4	Oct 19 - 22	6,000	13	55	209	375	584
5	Oct 26 - 29	6,000	13	52	188	479	667
6	Nov 2 - 5	6,000	13	53	163	514	677
7	Nov 9 - 13	8,000	11	54	124	416	540
8	Nov 16 - 19	13,300	9	54	101	246	347
9	Nov 23 - 25	14,800	5	51	18	60	78
10	Nov 30 - Dec 3	14,700	6	51	26	95	121
11	Dec 7 - 11	23,400	7	53	15	20	35
12	Dec 14 - 17	15,300	7	52	43	83	126
				Totals	1,142	2,584	3,726

1/ Weekly average discharge during days sampled as measured at Keswick Dam by U.S. Bureau of Reclamation.
2/ Weekly average of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

Table 3. Distribution by reach of carcasses (adults and grilse) observed during the upper Sacramento River fall-run chinook salmon escapement survey, September- December 1998.

Week	Reach 1 (RM 298.5-295.0)		Reach 2 (RM 295.0-292.0)		Reach 3 (RM 292.0-284.0)		Reach 4 (RM 284.0-273.0)	
	M[1/]	C[2/]	M	C	M	C	M	C
1	25	3	41	0	9	1	6	0
2	56	0	36	10	16	16	13	5
3	92	14	110	17	39	15	19	8
4	135	11	184	8	123	16	101	6
5	164	7	262	29	93	19	85	8
6	138	13	239	32	131	24	82	18
7	140	22	152	46	91	39	47	3
8	181	21	51	6	60	7	12	9
9	3	0	3	1	47	18	4	2
10	16	1	50	5	40	7	2	0
11	0	11	0	8	0	12	0	4
12	0	28	0	44	0	46	0	8
Totals	950	131	1,128	206	649	220	371	71

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.

Table 4. Size and sex statistics for fresh fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1998.

Week	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
1	39	67.4	49-96	13	68.5	49-96	26	68.8	54-90
2	79	74.6	53-98	37	77.0	53-98	42	72.5	56-89
3	131	79.2	43-103	54	83.4	43-103	77	76.3	52-92
4	193	82.2	49-108	82	86.8	54-108	111	78.9	53-97
5	187	82.7	49-106	66	88.3	49-106	121	79.7	56-98
6	159	81.0	58-106	56	84.6	58-106	103	79.1	59-94
7	132	81.2	49-105	46	86.1	49-105	86	78.6	59-97
8	97	79.7	52-110	31	86.9	52-110	66	76.3	52-98
9	16	78.5	60-109	4	83.0	60-109	12	77.0	60-97
10	25	85.2	50-104	9	90.0	50-104	16	82.6	68-92
11	14	81.1	56-100	5	88.8	56-100	9	75.3	63-98
12	39	80.9	49-101	19	81.2	62-101	20	80.7	49-98
Total (mean)	1,111	(80.3)	43-110	422	(84.6)	43-110	689	(77.9)	49-98

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1998.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	82	607	73	349
Mean FL (cm)	61.8	79.8	62.4	89.3
Range FL (cm)	49-67	68-98	43-71	72-110
Standard Deviation	4.1	6.8	6.7	9.1

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1998.

	Adults		Grilse	
Week	Number	Percent	Number	Percent
1	13	33	26	67
2	49	62	30	38
3	113	86	18	14
4	175	91	18	9
5	176	94	11	6
6	142	89	17	11
7	124	94	8	6
8	85	88	12	12
9	12	74	4	25
10	24	96	1	4
11	11	79	2	21
12	32	82	7	18
Total(mean)	956	(86)	155	(14)

Grilse comprised 155 (14%) of the 1,111 measured carcasses (Table 6). The greatest number of grilse (30) was observed in the second week (5-8 October) (Figure 9). Adults comprised 956 (86%) of the measured carcasses. The greatest number of adults (176) was also observed during Week 5 (26 -29 October).

Sex Composition

Males comprised 37% (n=349) of the fresh adult carcasses examined, while females comprised 63% (n=607) (Table 7). Males comprised 47% of the grilse (n=73); females comprised 53% (n=82). Females comprised 62% (n=689) of the all fresh carcasses; males comprised 38% (n=422). The female to male ratio for adult spawners was nearly 1.9:1 (607:349) (Table 7 and Figure 10). Females dominated the adult population throughout the survey period. The grilse population was also mostly female (Figure 11).

Spawning Success

There were 678 females examined for egg retention (Table 8). Of these, 647 (96%) had completely spawned, 9 (1%) had only partially spawned, and 22 (3%) had not spawned. At least 73% of the females checked each week had completely spawned.

Population Estimates

Only fresh carcass data were used to calculate the Schaefer estimate. A total of 893 fresh adult carcasses was tagged and 237 (27%) were subsequently recaptured. Both fresh and decayed carcass data were used to calculate the Jolly-Seber estimate. A total of 2,671 fresh and decayed adult carcasses was tagged, and 651 (24%) were subsequently recaptured.

An estimate of 12,506 adult spawners was calculated using the Schaefer model (Tables 9 and 10). Since adults made up 88% of the total escapement based on carcasses measured (Table 6), a total escapement estimate of 14,211 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.88. An adult escapement estimate of 7,532 was calculated using the Jolly-Seber model (Table 11). This estimate was similarly expanded by dividing by 0.88 resulting in a total escapement estimate of 8,559 spawners.

The 1998 population estimates for salmon spawning in the upper Sacramento River from Cottonwood Creek to ACID Dam are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	14,211	8,559
Adult estimate	12,506	7,532
Grilse estimate	1,705	1,027

The estimated 1998 escapement (14,211) is considerably less than the 1956 -1998 average (67,015) for the section of stream from RBDD to Keswick Dam (Table 12 and Figure 12). Since most fall-run chinook salmon spawn between Cottonwood Creek and ACID dam, with very little spawning taking place upstream of ACID dam, the inclusion of the uppermost 3.5 miles of river (ACID dam to Keswick Dam) would have added little to the survey.

Hatchery Produced Spawners

Two adipose-clipped (hatchery produced) carcasses were collected. No CWTs were found. Both carcasses were female; one was 60 cm FL and one was 83 cm FL.

Table 7. Sex composition of fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1998.

	Adults				Grilse*			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	4	31	9	69	9	35	17	65
2	23	47	26	53	14	47	16	53
3	45	40	68	60	9	50	9	50
4	71	40	104	60	11	61	7	39
5	61	35	115	65	5	45	6	55
6	48	34	94	66	8	47	9	53
7	42	34	82	66	4	50	4	50
8	27	32	58	68	4	33	8	67
9	2	17	10	83	2	50	2	50
10	8	33	16	67	1	100	0	0
11	4	36	7	64	1	100	0	0
12	14	44	18	56	5	71	2	29
Total (mean)	349	(37)	607	(63)	73	(47)	82	(53)

* Based on length-frequency distributions, male grilse are defined as salmon ≤ 71 cm FL and female grilse as salmon ≤ 67 cm FL.

Table 8. Spawning completion (egg retention) summary for female fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1998.

Week	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	26	26	25(96)	1(4)	0(0)
2	42	42	40(95)	1(2)	1(2)
3	77	75	74(99)	1(1)	0(0)
4	111	110	105(95)	2(2)	3(3)
5	121	119	115(97)	0(0)	4(3)
6	103	101	96(95)	1(1)	4(4)
7	86	84	80(95)	1(1)	3(4)
8	66	65	62(95)	0(0)	3(5)
9	12	11	8(73)	1(9)	2(18)
10	16	16	16(100)	0(0)	0(0)
11	9	9	8(89)	1(10)	0(0)
12	20	20	18(90)	0(0)	2(10)
Totals (means)	689	678	647(96)	9(1)	22(3)

Table 9. Weekly summary of tagging and recapture of fresh adult chinook salmon carcasses during the upper Sacramento River escapement survey, September - December 1998.

Schaefer model capture-recapture data matrix

Week of recovery $_{(j)}$	Week of tagging $_{(i)}$ 1	2	3	4	5	6	7	8	9	10	Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
2	13										13	167*	12.85
3	1	7									8	261	32.63
4	1	3	24								28	542	19.36
5		2	6	42							50	649	12.98
6			6	18	40						64	663	10.36
7			1	5	14	30					80	634	12.68
8					3	4	12				19	314	16.53
9								3			3	64	21.33
10									2		2	107	53.50
11											0	31	0.00
12											0	112	0.00
$R_{(i)}$	15	12	37	65	57	34	12	3	2	0	(Tagged fish recovered)		
$T_{(i)}$	17	35	90	188	175	147	116	87	14	24	(Total fish tagged)		
$T_{(i)}/R_{(i)}$	1.13	2.92	2.43	2.89	3.07	4.32	9.67	29.0	7.00	0.00	(Ratio)		

Includes carcasses counted during week 1

Table 10. Upper Sacramento River adult fall-run chinook salmon population estimate using the Schaefer model based on tagging fresh carcasses with all captured untagged carcasses removed, September - December 1998.

Population estimate

Week of recovery $_{(j)}$	Week of tagging $_{(i)}$										Totals
	1	2	3	4	5	6	7	8	9	10	
2	189										189
3	37	666									703
4	22	169	1,130								1,321
5		76	189	1,577							1,842
6			151	539	1,272						1,963
7			31	183	545	1,645					2,404
8					152	286	1,917				2,355
9								1,856			1,856
10									749		749
11											0
12											0
Subtotals	248	911	1,502	2,299	1,969	1,930	1,917	1,856	749	0	13,382
Tags		-35	-90	-188	-175	-147	-116	-87	-14	-24	-876
								Population estimate -			12,506

Table 11. Weekly summary of tagging and recapture of both fresh and decayed adult chinook salmon carcasses during the upper Sacramento River escapement survey, September - December 1998.

Jolly-Seber capture-recapture data matrix

Week of recovery$_{(j)}$	Week of tagging $_{(i)}$										Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$
	1	2	3	4	5	6	7	8	9	10		
2	21										21	175*
3	4	18									22	275
4	2	3	64								69	583
5		2	18	110							130	729
6			8	40	120						168	767
7			2	10	41	94					147	631
8					6	15	54				75	370
9						1	3	10			14	75
10								2	3		5	110
11										0	0	31
12										0	0	112
Tags recovered$_{(i)}$	27	23	92	160	167	110	57	12	3	0	<- Tagged fish recovered	
Carcasses Tagged$_{(i)}$	46	76	205	483	548	527	382	264	46	94	<- Total fish tagged	

* Includes carcasses examined during Week 1.

Table 12. Annual fall-run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from RBDD to Keswick Dam, 1956 - 1998.

Year	Totals *	Year	Totals
1956	84,716	1978	32,235
1957	47,300	1979	47,758
1958	99,300	1980	21,961
1959	249,600	1981	26,261
1960	210,000	1982	17,731
1961	134,700	1983	26,226
1962	115,500	1984	36,898
1963	135,200	1985	51,647
1964	140,500	1986	67,958
1965	98,900	1987	76,039
1966	107,900	1988	65,204
1967	78,100	1989	48,512
1968	95,600	1990	32,225
1969	114,600	1991	19,272
1970	65,950	1992	26,912
1971	52,247	1993	33,923
1972	33,559	1994	31,017
1973	40,424	1995	28,030(26,548)**
1974	45,590	1996	30,194(28,890)
1975	52,248	1997	95,505(26,191)
1976	43,612	1998	4,824(14,211)
1977	15,784	Mean = 67,015***	

* Estimates for years 1968 through 1985 were based on ladder counts made at RBDD during the entire run. Estimates for years after 1985 were based on ladder counts made at RBDD during a portion of the run.

** Results of carcass surveys, not used in calculating mean.

*** Average was calculated using annual escapements estimates from the 1956 through1998 period.

DISCUSSION

Carcass surveys have been annually conducted on the Sacramento River since 1995 to acquire data on the river's fall-run chinook spawning population. Our purpose was to determine if this method would provide reliable information on abundance and age and sex composition of the spawner population, temporal and spatial distribution of spawning and pre spawning mortality (egg retention), and if these data in combination with results of other investigations (e.g., redd surveys and RBDD fish counts) could be used to identify any influences of flow, temperature, channel morphology, and other habitat conditions on the functioning of the river's fall-run population. Results obtained during the four survey years (1995-1998) are inconclusive, however it appears that this approach will provide the targeted information needed to improve our understanding of the dynamics of the river's fall-run population, and ultimately its relationship with manageable habitat conditions.

C Fall-run spawner escapement estimates have been very consistent during the four survey years (Table 13). The estimates for the first three years were essentially identical ranging from 25,890 to 26,246 salmon (mean=26,209, SD=268). Tag recovery rates were also nearly equal during the first three years (mean=32%. SD=0.82). The population estimate decreased in 1998 to 14,211 as did the recovery rate (24%).

Since flows and water clarity were noticeably different in 1998, when both total estimate and recovery rate were lower than during the first three survey years, we evaluated the relationship between recovery rate and flow, water clarity and number of fish tagged to identify any biases potentially associated with these variables. No relationships were observed between weekly tag recovery rates and flow (r^2=0.07), water clarity (r^2=0.02) or number of fish tagged (r^2=0.24).

Escapement estimates were also made for the reach from RBDD to Keswick using fish counts made at RBDD and redd distribution data. Escapement estimates for this reach were similar to the carcass survey based estimates in 1995 (28,030 v. 26,546) and 1996 (30,184 v. 25,890), but were considerably different in 1997 (95,505 v. 26,191) and 1998 (5,386 v. 14,211).

The differences may be due to the difference in the survey reach lengths. The RBDD count based estimate includes 31.5 miles not covered in the carcass survey (3.5 miles upstream of the carcass survey reach, from ACID to Keswick Dam, and 28 miles downstream from the survey reach from Cottonwood Creek to RBDD). Redd survey data, however, indicate that few salmon spawn upstream of ACID and downstream of Cottonwood Creek. The carcass survey results also indicate that spawning activity decreases moving downstream, less than 12% of the observed carcasses were found in the lower 11 miles (43%) of the survey reach. Comparison of the 1995 and 1996 results suggest that from 86 to 95% of spawning occurs within the carcass survey reach. A

Table 13. Comparison of results of carcass surveys conducted on the upper Sacramento River fall-run chinook salmon spawner population from 1995 through 1998.

	1995	1996	1997	1998
Total estimate	26546	25890	26191	14211
% Adult	91	79	90	86
% Grilse	9	21	10	14
% Female adult	66.4	65.7	59	63.5
% Male adult	33.6	34.3	41	36.5
% Female all	62	54	55	63
% Male all	38	46	45	37
Tag recovery rate (%)	33	32	31	24
Spawning success	94	87	92	96
Reach 1 %	40	23	28	29
Reach 2 %	21	37	34	36
Reach 3 %	23	26	24	23
Reach 4 %	16	14	14	12
Peak carcass count (all)	6 11/5-11	5 10/28-11/1	5 10/27-30	6 11/2-5
Flow range	4800-6500	6700-27700	4200-6300	6200-23400
Temperature range	53-57	53-56	53-57	51-55
Grilse size criteria (male)	64	73	72	71
Grilse size criteria (female)	64	64	66	67

similar comparison suggests that only 27% of spawning occurred in the carcass survey reach in 1997. Since the carcass based survey was nearly 3-fold the RBDD based estimate, no such comparison could be made. However, since we observed 3,726 carcasses in 1998, nearly 70% of the redd based estimate, it is extremely likely that the RBDD based method drastically underestimated spawner escapement.

C Age composition of the spawner population varied from 91% to 79% adults (Table 13). There was no relationship observed between percent grilse and the estimated adult population for the subsequent year.

C Sex composition varied only slightly during the four survey years (Table 13). The percentage of female adults ranged from 59% (1997) to 66.4% (1995) (mean=63.7, SD=2.9). The total percentage of female (grilse and adult) ranged from 54% (1996) to 63% (1998) (mean=58.5, SD=4.0).

C Spatial spawning distribution (based upon location of fresh carcass collection) varied slightly within Reaches 1 and 2 and was fairly consistent in Reaches 2 and 4 (Table 13). The majority of spawning occurred within Reaches 1 and 2, accounting for at least 60% of all spawning (mean=62%, SD=1.9) Spawning distribution within these two reaches was predominantly within Reach 2, nearly twice as much spawning was observed in Reach 1 versus 2 in 1995, the only year when spawning was greater in Reach 1. Spawning within Reach 3 was very consistent (mean=24, SD=1.2). Similarly, spawning in Reach 4 was also very consistent (mean=14%, SD=1.4).

C Spawning consistently peaked during the last week of October and first week of November. Fresh and decayed carcasses were also observed during the first survey week (typically the first week of October) of each year.

C Spawning success, measured as percentage of completely spent female carcasses, ranged from 87% to 96%. The lowest spawning success was measured in 1996 when the overall population was highest; the highest success was measured in 1998 when overall population was lowest.

C The contribution of hatchery produced salmon to the fall-run spawner population appears to be very low. Only two adipose clipped fish were observed, on grilse and one adult. These two fish were likely produced at Coleman National Fish Hatchery (CNFH) then marked, tagged and released into the upper Sacramento River system. (The majority of adipose clipped salmon that return to the upper Sacramento River are from CNFH). Since 7% of the fall-run production at CNFH are typically marked, one adipose clipped fish potentially represents about 14 CNFH produced fish (i.e., 1 marked and 13 unmarked). The estimated, minimum proportion of hatchery produced spawners was 0.4% adults and 2.7% grilse.

ACKNOWLEDGMENTS

The California Department of Fish and Game recognizes the efforts of Chris Cox, Paul Divine, John Galos, Jordan McKay, James Lyons, Carrie Savage, Mike Spiker, Jonathan Sutliff, and Jada-Simone White. Their efforts in the collection of field data are greatly appreciated. The data collection was funded by the FWS as a part of a cooperative agreement with the DFG as authorized by the CVPIA (PL. 102-575).

LITERATURE CITED

Boydstun, L.B. 1994. Evaluation of the Schaefer and Jolly-Seber methods for the fall-run chinook salmon, *Oncorhynchus tshawytscha,* spawning run into Bogus Creek, Upper Klamath River, Calif. Fish & Game 80(1):1-13.

Fry, D.H. 1961. King salmon spawning stocks of California Central Valley, 1940-1959. Calif. Fish & Game, 47(1):55-71.

Law, P.M.W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif. Fish & Game 80(1):14-28.

Menchen, R.S. (Editor). 1970. King (chinook) salmon spawning stocks in California's Central Valley, 1969. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 70-14, 26 p.

Ney, J.J. 1993. Practical Use of biological statistic, *in* Kohler and Hubert (Editors). Inland fisheries management in North American. American Fisheries Society. Bethesda, Maryland. pp 137-158.

Needham, P.R., H.A. Hanson, and L.P. Parker. 1943. Supplementary Report on investigations of fish-salvage problems in relation to Shasta Dam. Special Scientific Rpt. No. 26, U.S. Dept. of Interior, USF&WS, 150 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dep of Environ., Fish. And Mar. Serv. Bull.191. 382 p.

Schaefer, M.B. 1951. Estimation of the size of animal population by marking experiments. USF&WS Bull. 52:189-203.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey: Lower American River, 1991 - 1992, Final report. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow and Habitat Evaluation Program.

Snider, B., B. Reavis and L. Hanson. 1997. Upper Sacramento River fall-run chinook salmon escapement survey, September - December 1995. Final report. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow and Habitat Evaluation Program.

Snider B., B. Reavis, and S. Hill. 1998. Upper Sacramento River fall-run chinook salmon escapement survey, September - December 1996. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Habitat Evaluation Program.

Snider B., B. Reavis, and S. Hill. 1998. Upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997 Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Habitat Evaluation Program.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

Snider, B. And K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall 1993. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

Taylor, S.N. (Editor). 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 74-12. 32 p.

FIGURES

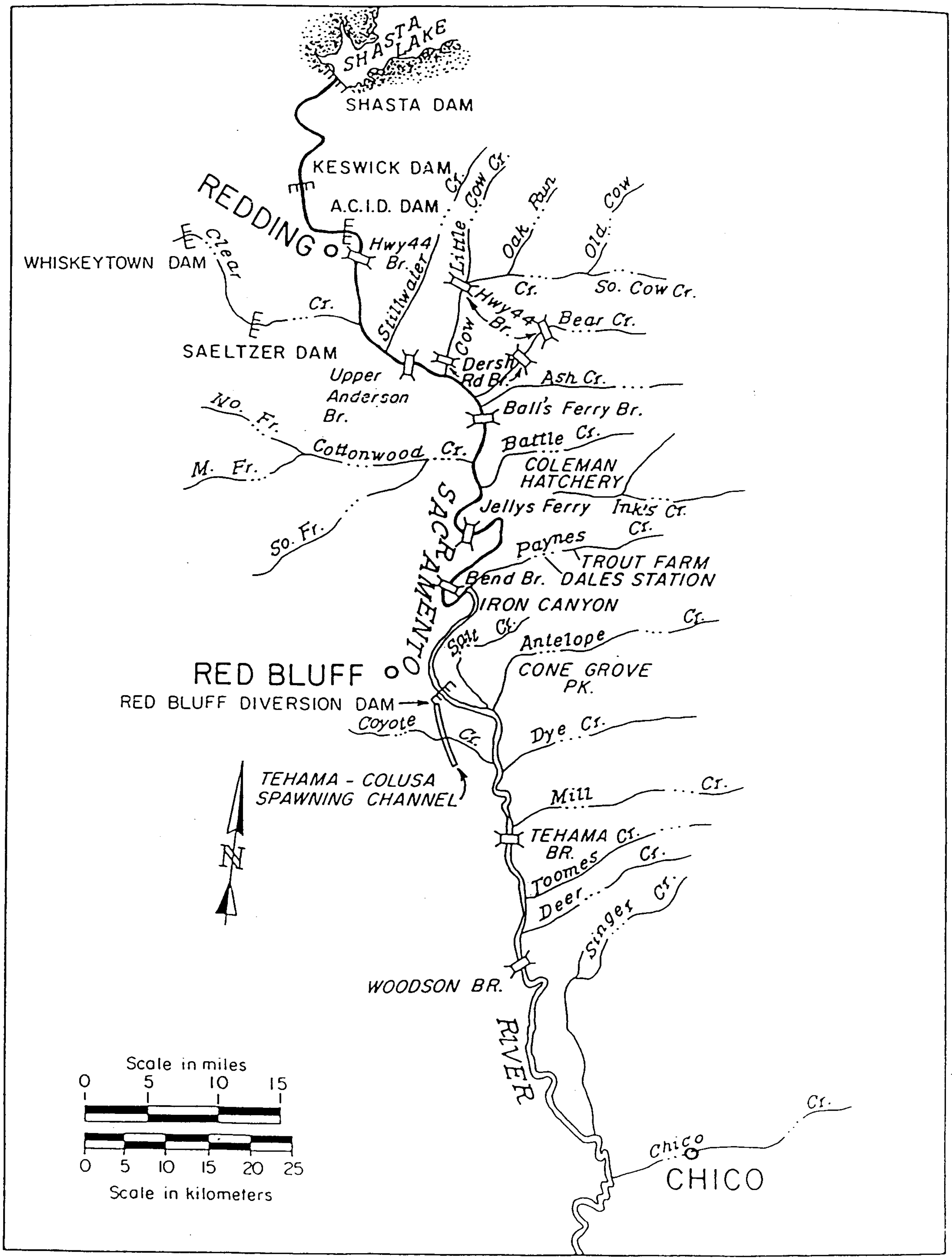


Figure 1. Upper Sacramento River.

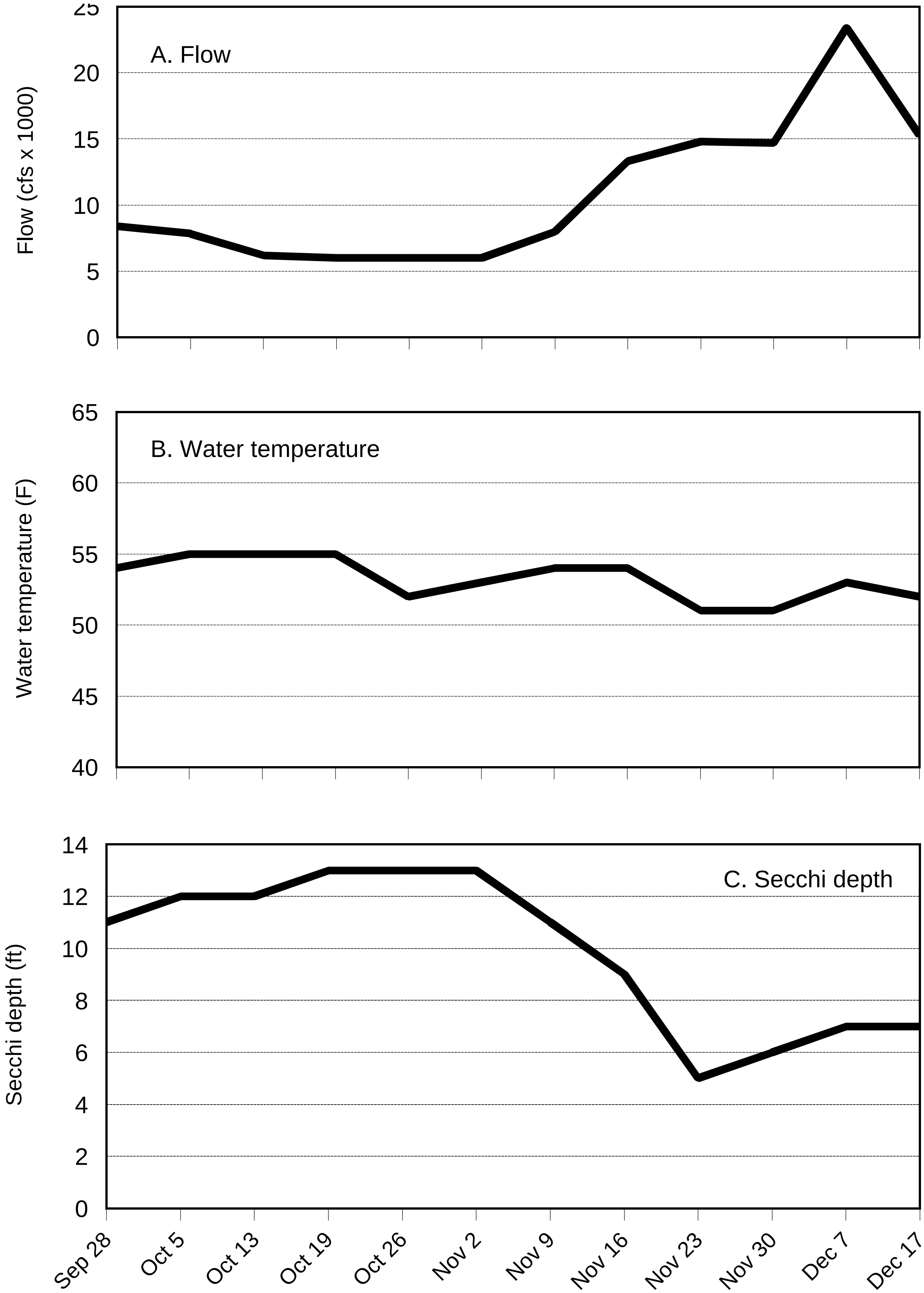


Figure 2. Mean daily flow at Keswick Dam (A), water temperature (B), and Secchi depth (C), measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

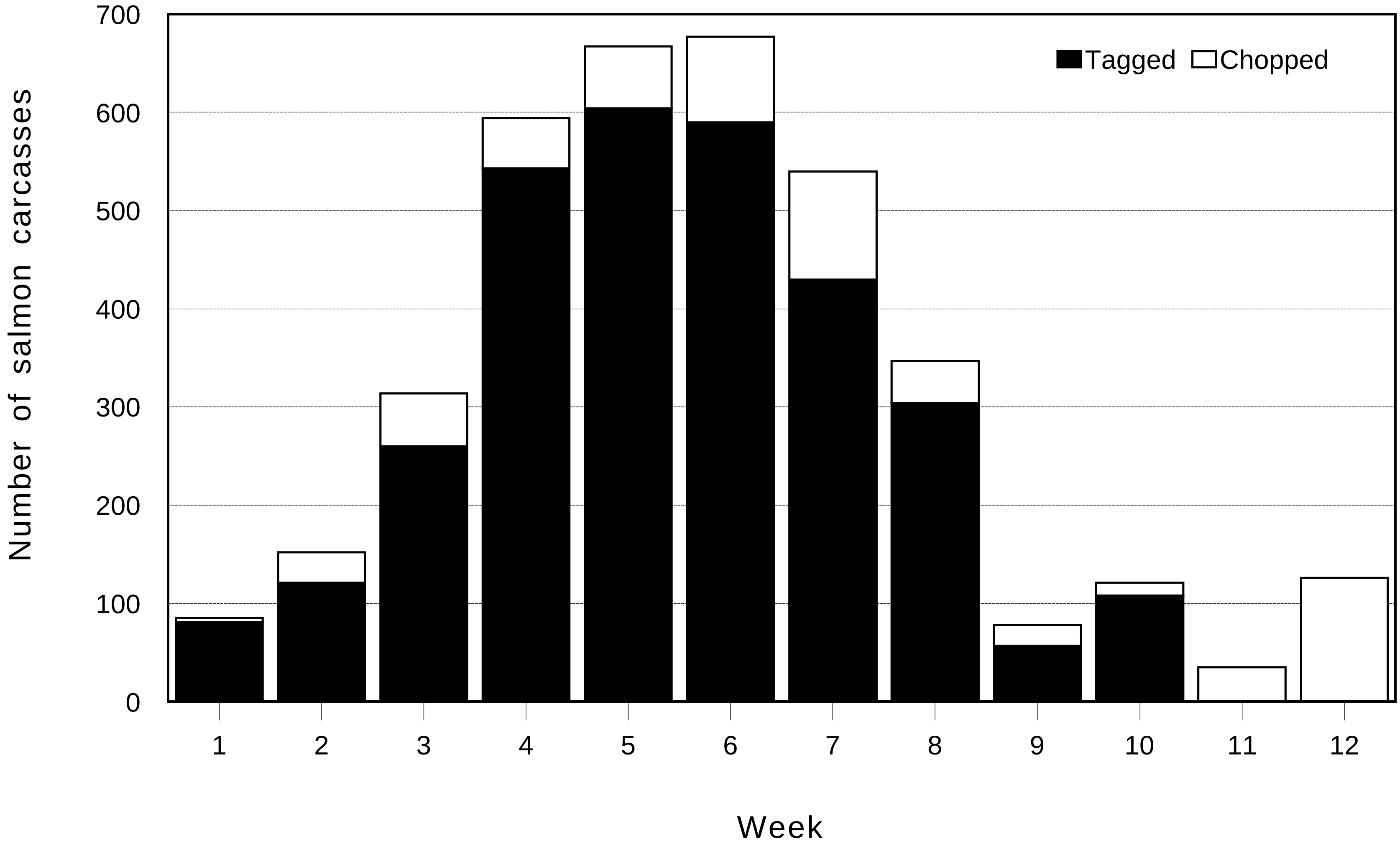


Figure 3. Weekly distribution of both fresh and decayed carcasses (adult and grilse) observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

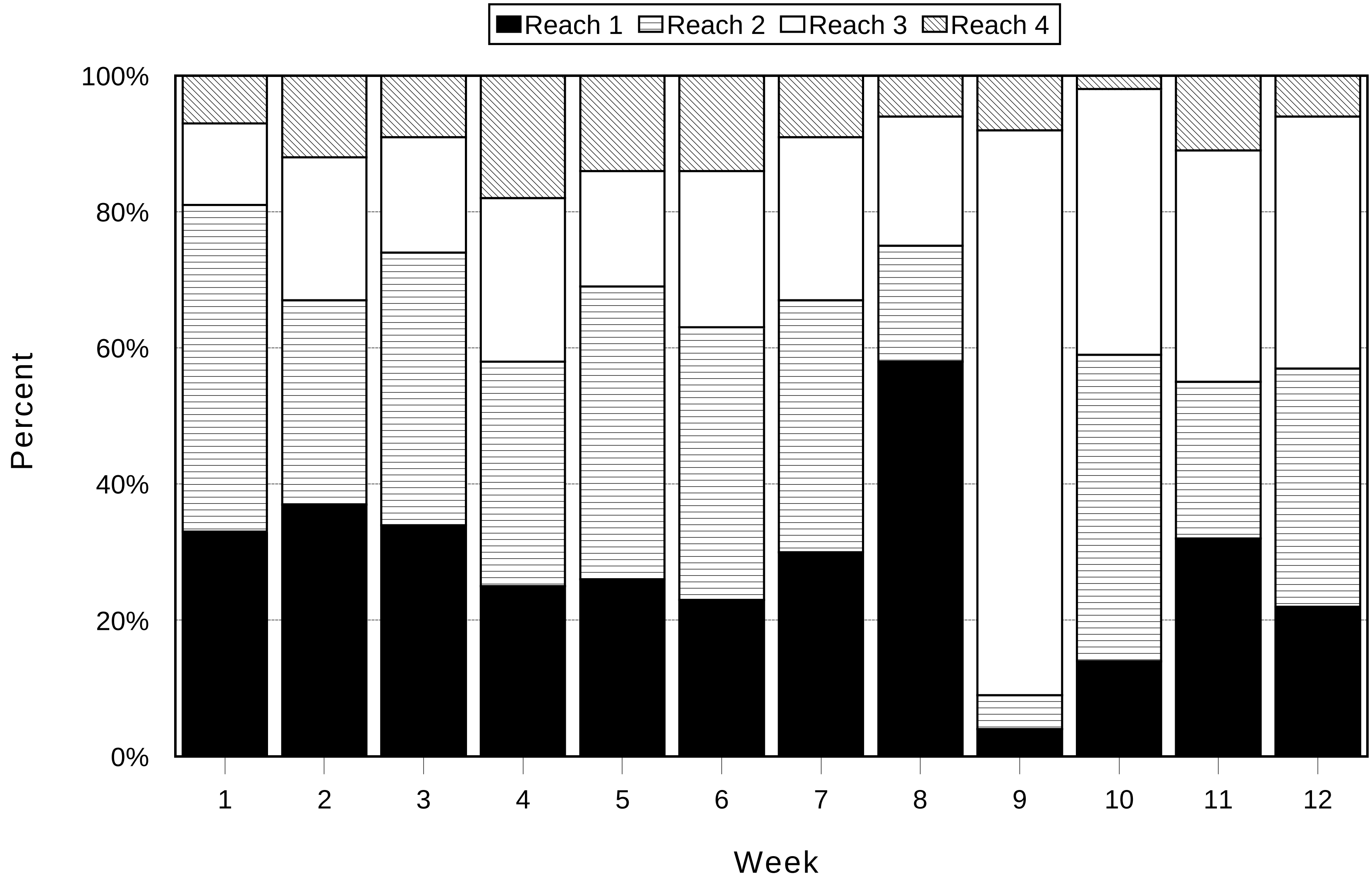


Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

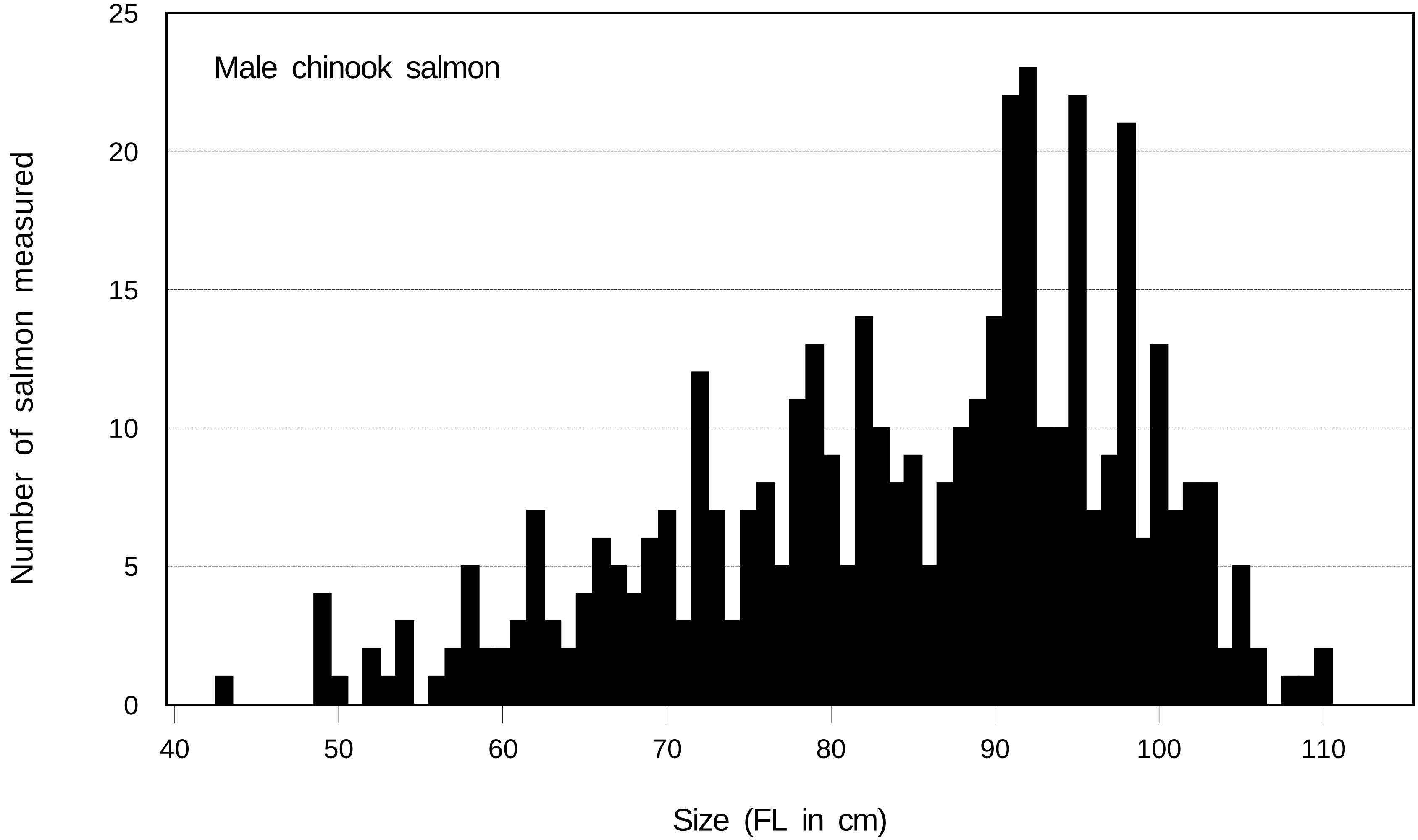


Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

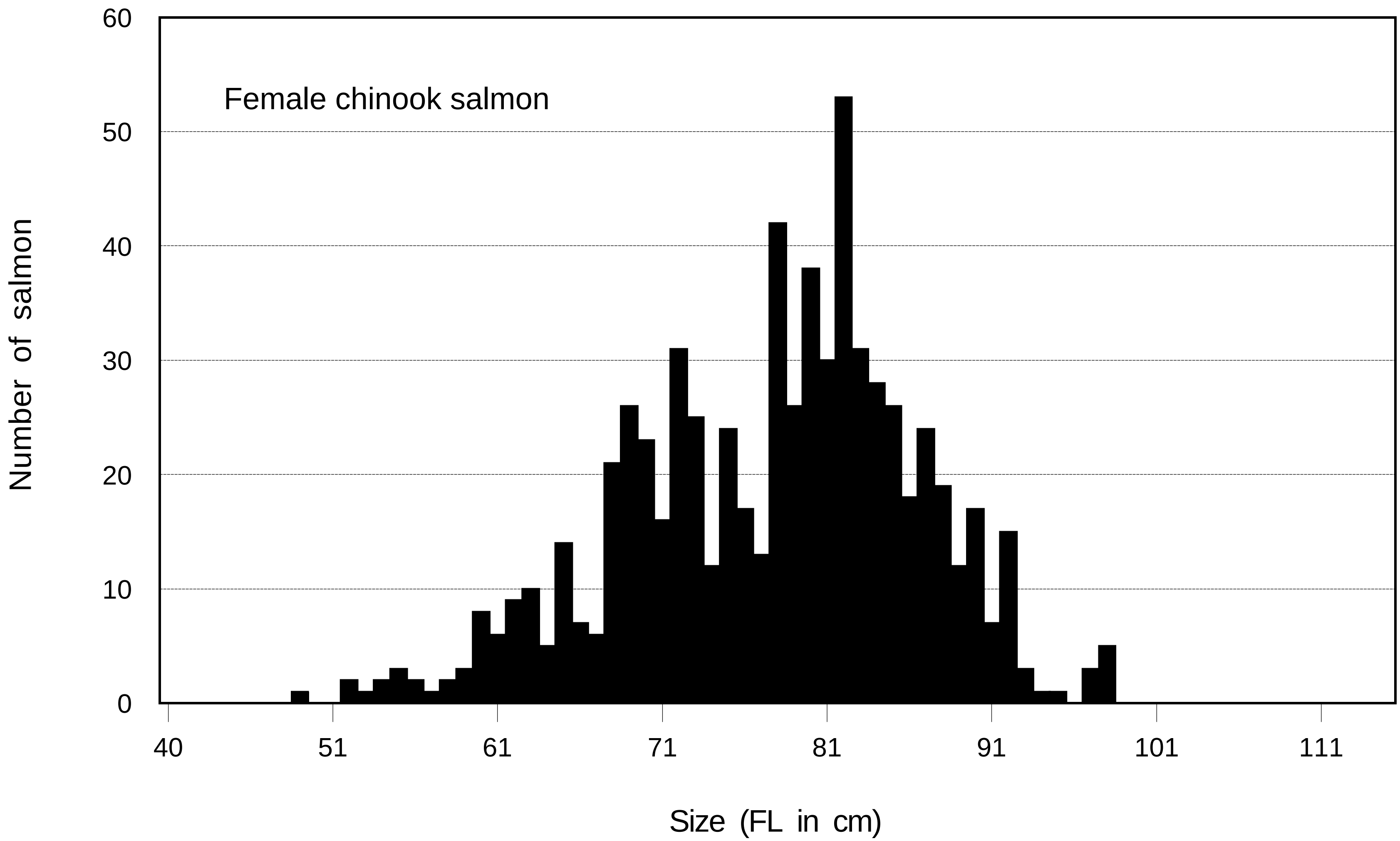


Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

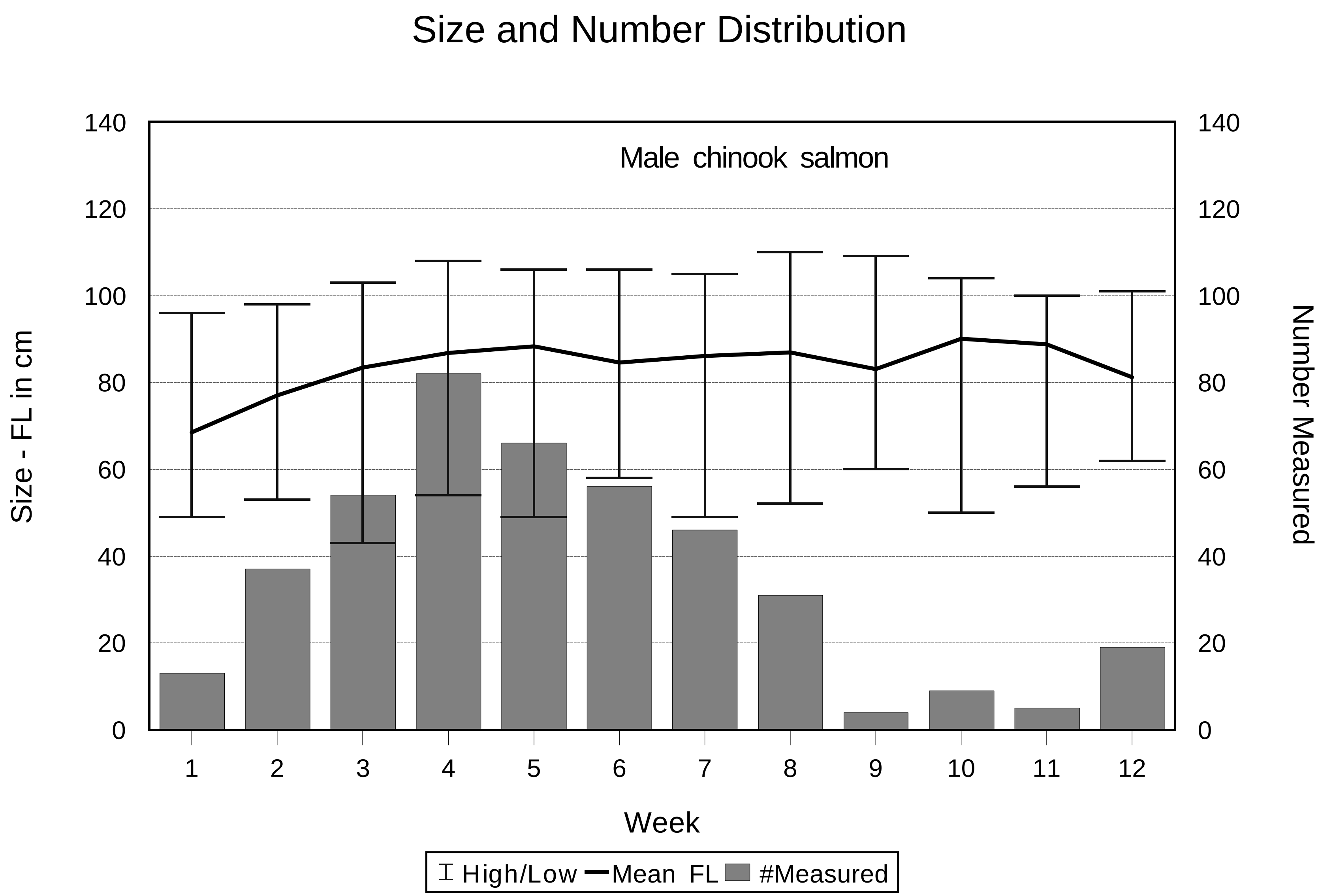


Figure 7. Weekly mean size, size range, and number of male chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

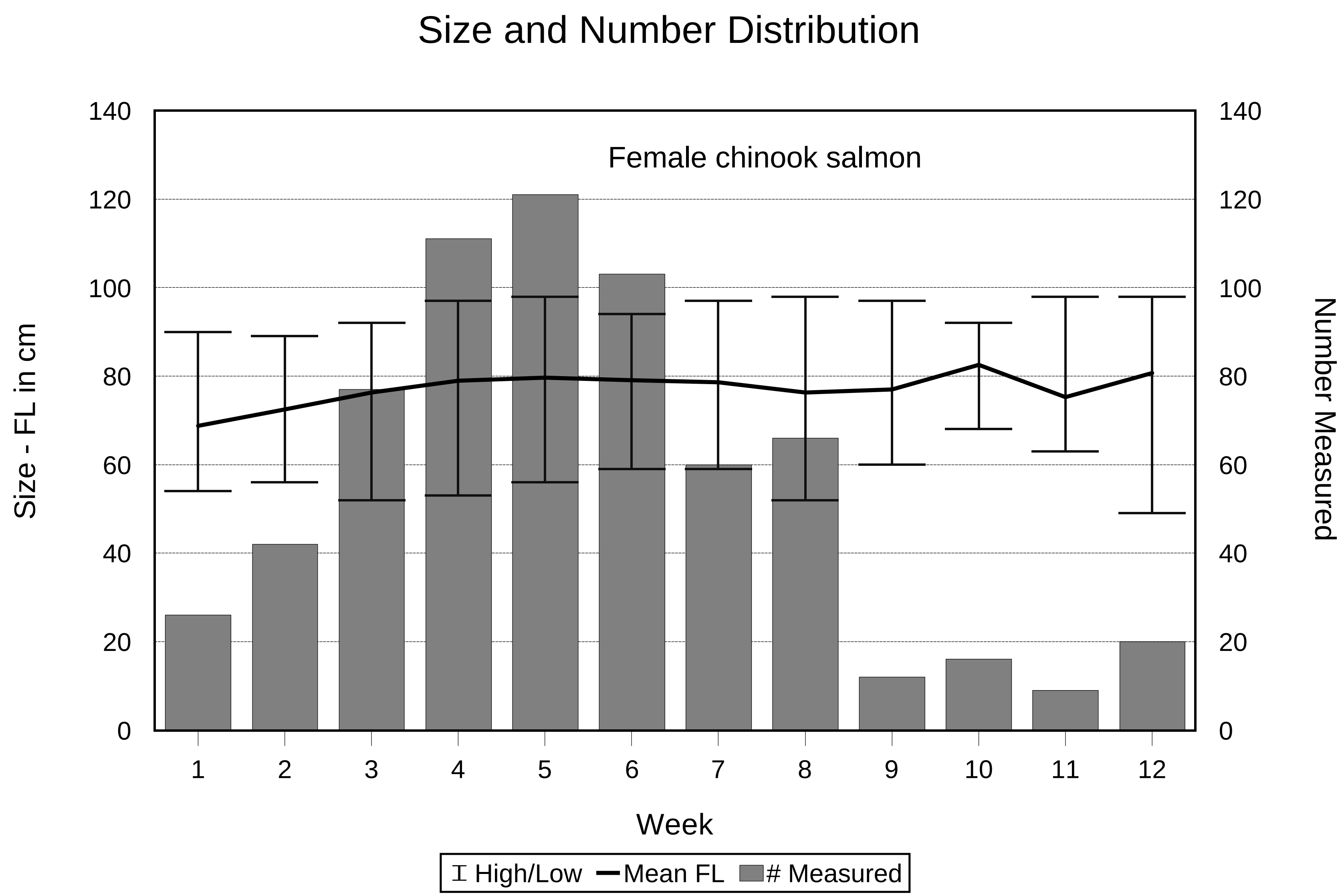


Figure 8. Weekly mean size, size range, and number of female chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

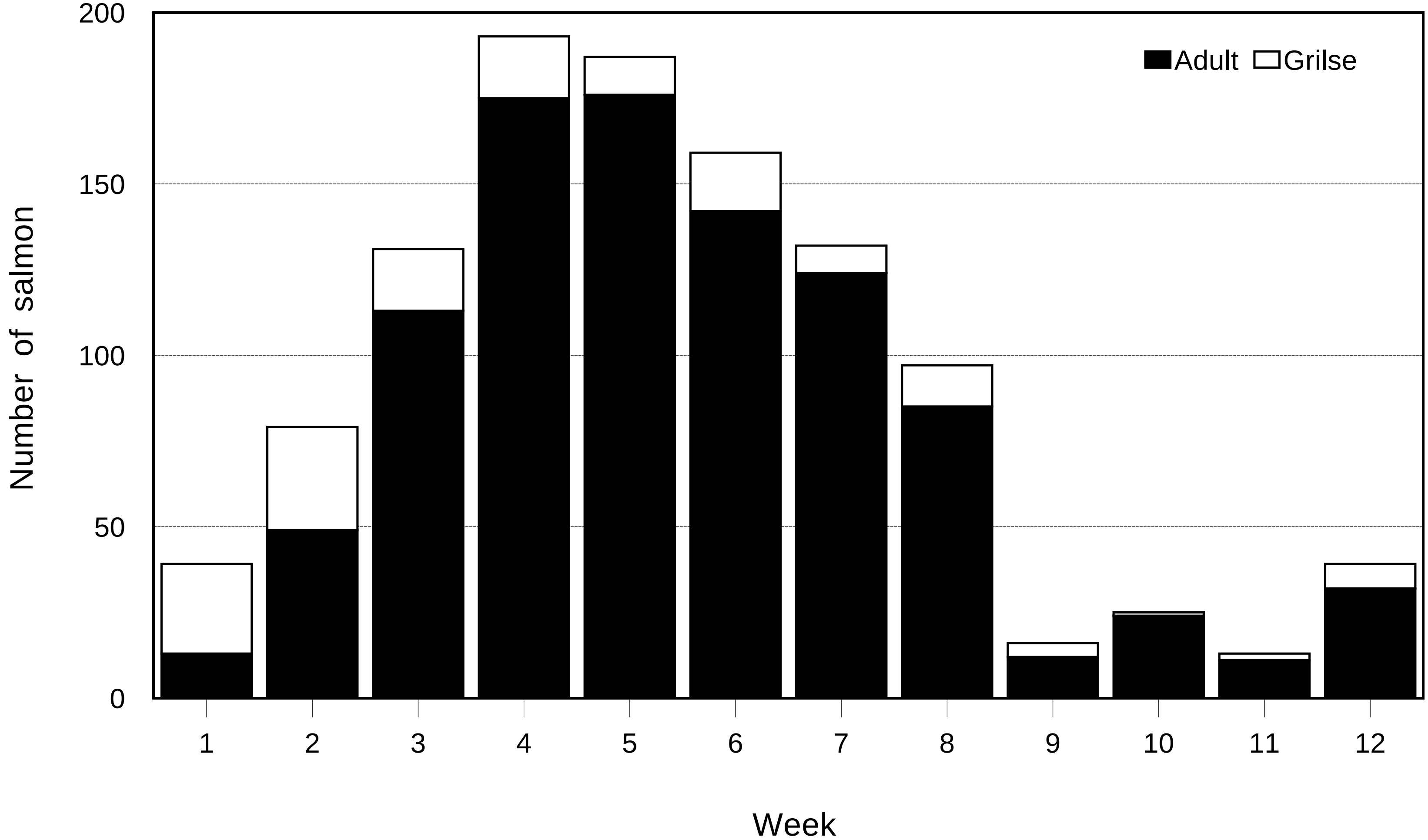


Figure 9. Adult and grilse compostion of chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

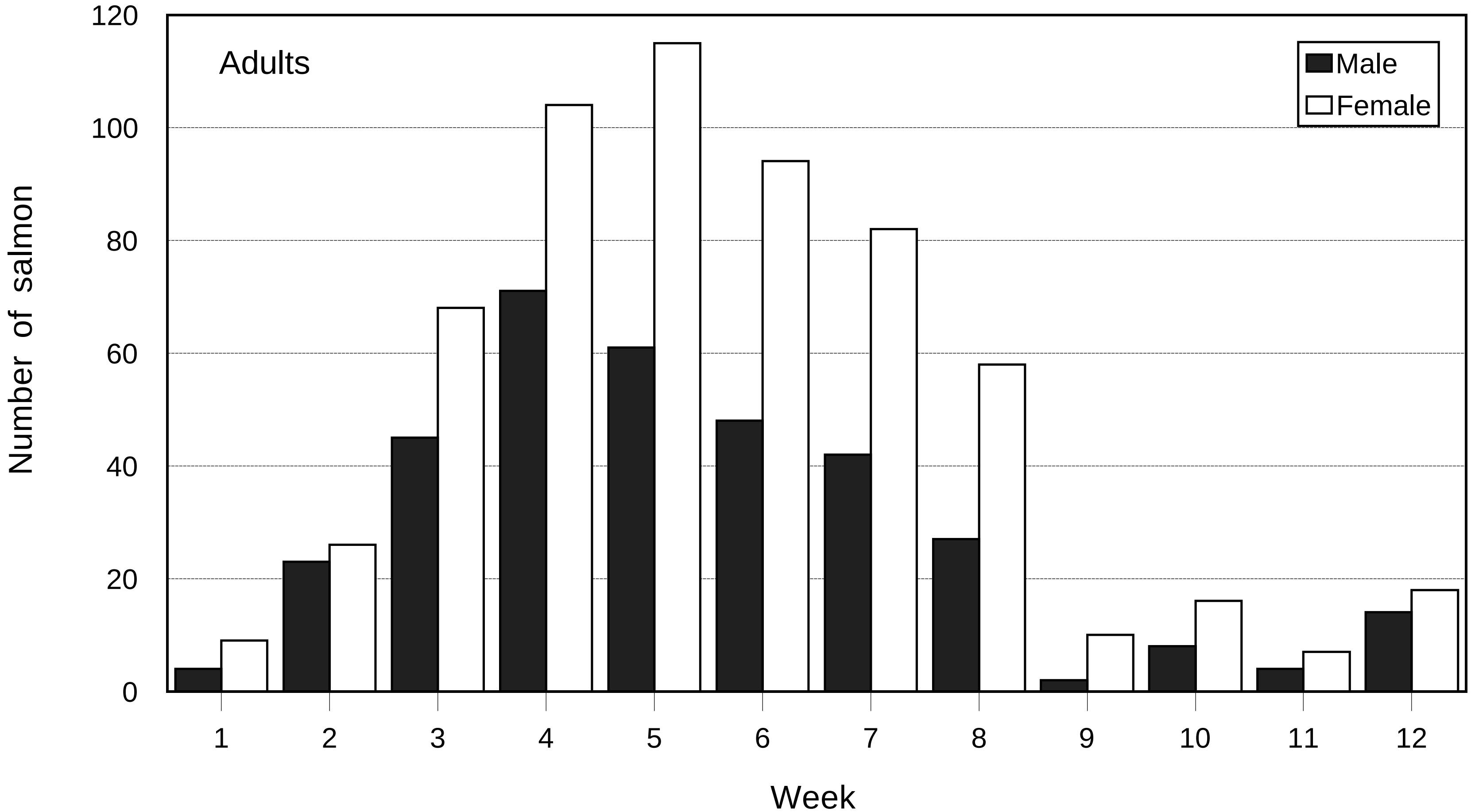


Figure 10. Weekly gender (sex) distribution of adult-sized chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

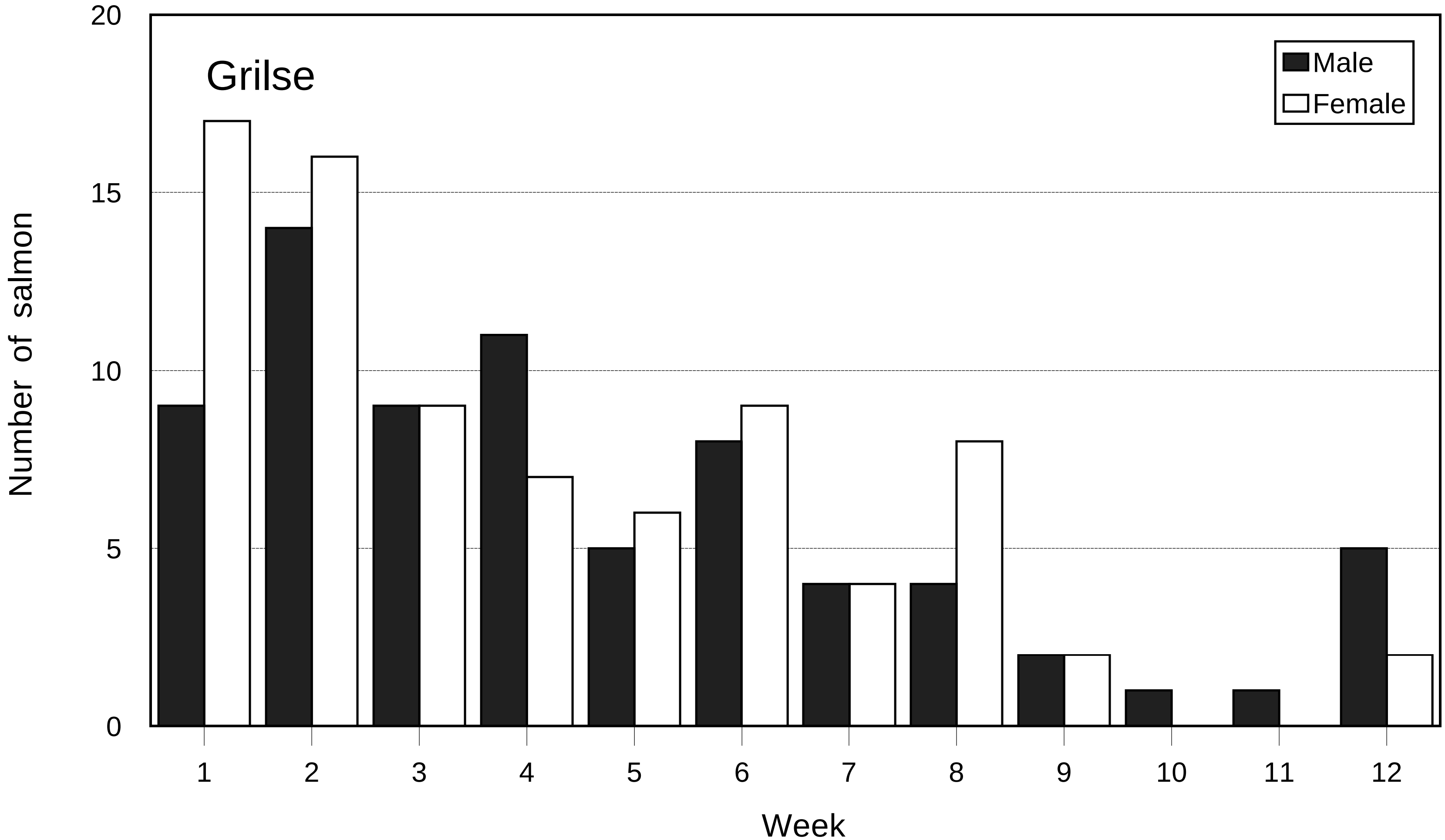


Figure 11. Weekly gender (sex) distribution of grilse-sized chinook salmon measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

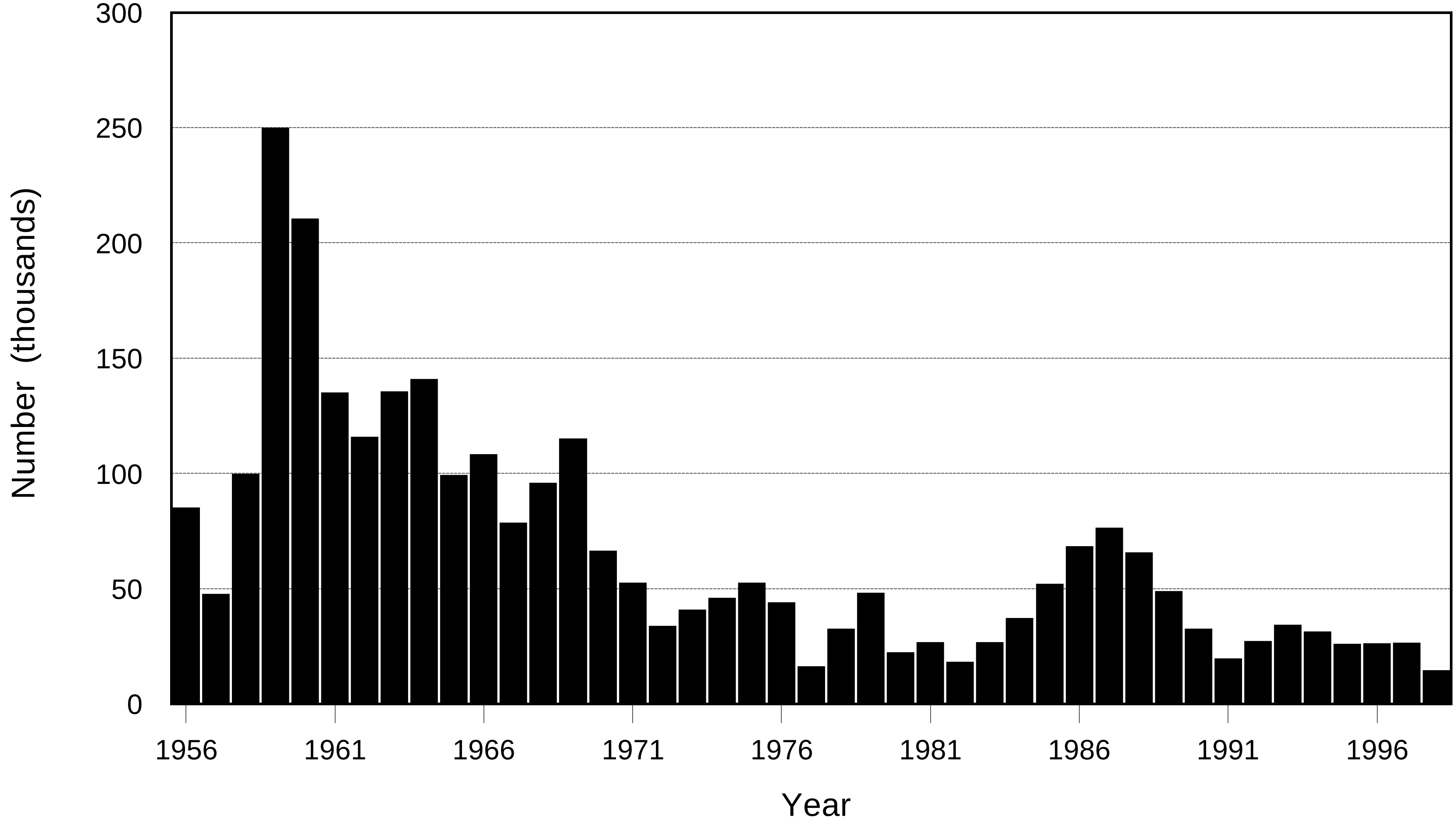


Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1998).

APPENDIX IV

Late-fall-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

Upper Sacramento River
Late-Fall-Run Chinook Salmon Escapement Survey
December 1998–April 1999

by

Bill Snider
Bob Reavis
and
Scott Hill

Stream Evaluation Program
Technical Report No. 99-3
November 1999

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

Upper Sacramento River Late-Fall-Run Chinook Salmon Escapement Survey December 1998–April 1999 1/

by

Bill Snider
Bob Reavis
and
Scott Hill

November 1999

1/ This work was supported by funds provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program, as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report 99-3.

TABLE OF CONTENTS

Summary

A late-fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during the winter and spring period of 1998–1999 to acquire data on spawner abundance, age population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the third year a late-fall-run escapement survey was conducted as part of a multi-year investigation by the Department of Fish and Game (DFG) to determine salmon habitat requirements in the Sacramento River system.

Late-fall-run spawning occurs from winter through early spring when survey conditions can be affected by high flows or reduced water clarity. Suitable survey conditions may last from only a few days to several months. During the first survey year, initiated in January 1996, high flows and extremely poor visibility forced suspension of the survey in late January. Survey conditions were substantially better during the winter-spring period of 1997–98 allowing a season-long survey.

Weekly surveys were conducted from 28 December 1998 through 28 April 1999. The surveys covered the 16.5-mile long section of the Sacramento River between Anderson-Cottonwood Irrigation District (ACID) Dam, at river mile (RM) 298.5, and Anderson River Park (RM 282.0). ACID Dam is located 3.5 miles downstream of Keswick Dam, the upstream limit to salmon migration. Flow ranged from 5,500 cubic feet per second (cfs) during weeks 2 and 3 (4–13 January 1999) and weeks 14 and 15 (29 March–7 April 1999), to 29,800 cfs in week 11 (8–10 March 1999). Water clarity ranged from 5 ft during week 4 (11–3 January) to 10 ft during weeks 3, 5, and 6 (11–13 and 26–28 January and 1–3 February 1999). Water temperature ranged from 47° F in week 11 (8–10 March 1999) to 52° F in week 18 (26–28 April 1999).

We observed 2,206 late-fall-run carcasses (450 fresh and 1,756 decayed). We measured (length) and sexed 435 fresh carcasses. Based on the fresh carcass measurements, 30% of the spawner population were male adults (>2-years old), 56% were female adults, 5% were male grilse (2-years old), and 9% were female grilse. Examination of 275 fresh female carcasses for egg retention showed that 267 (93%) had completely spawned, three (1%) still contained a substantial number of eggs, and five (2%) were unspawned.

Water clarity and flow conditions were more favorable for a tag recapture study in 1998–99 than during 1997–98. During 1997–98 water clarity equaled or exceeded 5 ft during only one-third of the weeks. Water clarity equaled or exceeded 5 ft during the entire 1998–99 survey. Similarly, during 1997–98, flows exceeded 20,000 cfs for one-half the season. In 1998–99, flows only exceeded 20,000 cfs for one-fifth of the season.

The total spawner escapement of 8,683 (1,216 grilse and 7,467 adults) was estimated using the Petersen formula, and 9,577 (1,341 grilse and 8,236 adults) using the Schaefer formula.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive late-fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey on the upper Sacramento River during the winter-spring period of 1998–99 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and DFG have signed a "Cooperative Agreement" by which the FWS will fund DFG to conduct studies to determine flow needs of salmonids in the upper Sacramento River.

The primary charge of STEP - to improve understanding of the relationships between anadromous salmonids and habitat in the upper Sacramento River - requires reliable estimates of spawner populations to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys allows this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Carcass tag-and-recapture surveys have been routinely used to estimate fall-run chinook salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for subsequent recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). This is the third year a carcass tag-and-recapture survey was conducted in the upper Sacramento River to estimate late-fall-run escapement. A late-fall-run spawner escapement survey attempted in 1996 was severely hampered by high flows. A complete survey was carried out in 1998 (Snider *et al.* 1998). Extremely high flow conditions prevented a late-fall-run survey in 1997.

Three models have been used by the DFG to estimate escapement based on carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for small spawner populations (e.g., recent upper Sacramento River winter-run populations) (Snider *et al.* 1999). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate escapement in the

Yuba River.

Based on Law's (1994) analysis, the Schaefer and Petersen models will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate spawner escapement in the Central Valley. This Jolly-Seber model was first used to estimate escapement in the Central Valley in 1988. It is more accurate when model assumptions are met and recovery rates are $\geq$10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fishery managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.)[1/]. Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

METHODS

The 1999 late-fall-run salmon spawner escapement survey was conducted from 28 December 1998 through 28 April 1999. The 16.5-mile-long stream segment from ACID Dam (RM 298.5) downstream to Anderson River Park (RM 282) was divided into three reaches (Figure 1 and Table 1). Each reach was surveyed once per week.

Table 1. Location of reaches surveyed during the upper Sacramento River late fall-run chinook salmon escapement survey, December 1998–April 1999.

Reach	Location	River mile (length in miles)
1	ACID Dam to Cypress St. Bridge	298.5–295.0 (3.5)
2	Cypress St. Bridge to Bonnyview Bridge	295.0–292.0 (3.0)
3	Bonnyview Bridge to Anderson River Park	292.0–282.0 (10.0)

Surveys were primarily conducted using one boat with two observers per boat. The observers attempted to locate and collect carcasses as the boat traversed the river between the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included: i) those previously tagged, ii) those on shore in a "leathery condition"; and, iii) those in the lower end of Reach 3 (the most downstream reach) that would likely wash out of the survey area and never be recovered. Tagged carcasses were

1/ Personal communication with Frank Fisher (DFG-Inland Fisheries Division, Red Bluff) and Fred Meyer (DFG Region 2, Sacramento, retired).

released into running water for recapture. Data collected to estimate population size included the numbers tagged, chopped, and recovered. All carcasses were examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from a subsample of the fresh carcasses included gender, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, as partially spent if a substantial amount of the eggs remained, and unspent if the ovaries appeared nearly full of eggs. Carcasses were also examined for adipose-fin marks indicating presence of a coded-wire tag.

Our objective was to estimate the late-fall-run salmon natural escapement in the upper Sacramento River, preferably using the more accepted Schaefer or Jolly-Seber models. Since there were no recoveries from four of the 16 weeks that tag groups were released, the results for these weeks were lumped to calculate an estimate using the Schaefer model. The Petersen model was also used.

The formulas used to derive the escapement estimates (E) are as follows:

1. Schaefer model (as described by Taylor 1974): $E = N_{ij} = R_{ij}(T_i C_j / R_i R_j) - T_i$

where:

N_{ij} = Population size in tagging period *i* recovery period *j*,
R_{ij} = number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
T_i = number of carcasses tagged in the *i*th tagging period,
C_j = number of carcasses recovered and examined in the *j*th recovery period,
R_i = total recaptures of carcasses tagged in the *i*th tagging period, and
R_j = total recaptures of tagged carcasses in the *j*th recovery period.

This model differs from the original in that the number of tags applied after the first week is subtracted from the population estimate to account for sampling with replacement. Schaefer's original model was based on sampling without replacement while in salmon survey conditions, sampling occurs with replacement.

2. Petersen formula (3.7) as described by Ricker (1975):

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where, N = estimated spawning population,
M = number of carcasses marked during survey,
C = total number of carcasses examined during survey, and
R = number of marked carcasses recovered during survey.

Flow measurements for each survey day were obtained from the Keswick gauge operated by the

U.S. Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

RESULTS AND DISCUSSION

A total of 2,206 carcasses was observed (Table 2). Mean[2/] flow ranged from 5,500 cfs during weeks 2 and 3 (4–13 January 1999) and weeks 14 and 15 (29 March–7 April 1999) to 29,800 cfs during week 11 (8–10 March). Flow was greater than 20,000 cfs during 22 percent of the survey weeks (Table 2, Figure 2). Mean temperature ranged from 47° F during week 11 (8–10 March) to 52° F during week 18 (26–28 April) (Table 2, Figure 2). Mean water clarity (Secchi depth) ranged from 5 ft in week 4 (19–21 January) to 10 ft during weeks 3, 5, and 6 (12–13 January and 26 January–3 February) (Table 2, Figure 2).

Temporal Distribution

Most carcasses were observed between 28 December 1998 and 28 January 1999 (57%). Twenty-two percent of the carcasses were observed during February, 16% during March, and 5% during April (Table 2 and Figure 3). Spawning appeared to be concentrated in first two weeks of January, however, the relatively high flow conditions that occurred from mid-February through mid-March may have restricted our ability to observe carcasses after the end of January.

Spatial Distribution

The majority of carcasses were observed in Reach 1 (46%, n = 1,017); 32% were observed in Reach 2 (n = 699), and 22% (n = 490) in Reach 3 (Table 3 and Figure 4). The spatial distribution may not accurately define spawning distribution since an unknown proportion of carcasses likely drifted downstream.

Size Distribution

Mean size of all measured carcasses was 84.4 cm FL (n = 435) (Table 4). Size ranged from 34 to 105 cm FL. Male salmon (n = 151) averaged 92.4 cm FL (range: 34 – 105 cm FL) (Figure 5). Female salmon (n = 284) averaged 82.1 cm FL (range: 52 – 102 cm FL) (Figure 6). The weekly mean size for males ranged from 82.0 to 101.5 cm FL (Figure 7). Weekly mean size for females ranged from 73.0 to 88.3 cm FL (Table 4 and Figure 8).

Length-frequency distributions were used to define a general size criterion to distinguish grilse (2-year-old salmon) and adults (>2-year-old salmon) for each sex (Figures 5 and 6). Both male (n = 22) and female (n = 40) grilse were defined as salmon ≤71 cm FL (Table 5). Male grilse averaged 63.3 cm FL (range: 34–70 cm FL, SD = 9.1); male adults (n = 129) averaged 94.0 cm

2/ Mean of daily measurements for week.

Table 2. General survey information for the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1998 – April 1999.

Week	Survey dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]		
					Fresh	Decayed	Total
1	Dec 28 –30 (1998)	6,000	6	48	72	340	412
2	Jan 4–6	5,500	9	49	58	184	242
3	Jan 1–13	5,500	10	48	51	168	219
4	Jan 19–21	19,100	5	49	38	139	177
5	Jan 26–28	11,700	10	49	42	170	212
6	Feb 1–3	7,200	10	48	60	227	287
7	Feb 9 – 11	15,000	9	48	19	100	119
8	Feb 16–19	26,200	8	48	4	16	20
9	Feb 22–26	23,600	8	48	16	50	66
10	Mar 1–4	27,800	8	48	12	34	46
11	Mar 8–10	29,800	7	47	5	20	25
12	Mar 15–17	14,700	8	49	18	73	91
13	Mar 22–24	6,200	7	48	19	104	123
14	Mar 29–31	5,500	8	48	17	51	68
15	Apr 4–7	5,500	8	49	7	17	24
16	Apr 12–14	9,300	8	50	7	25	32
17	Apr 19–21	9,000	9	51	3	23	26
18	Apr 26– 28	9,000	9	52	2	15	17
	Totals				450	1,756	2,206

1/ Mean flow during days sampled as measured at Keswick Dam by U.S. Geological Survey.
2/ Mean of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

FL (range: 72–105 cm FL, SD = 8.3). Female grilse (n = 40) averaged 66.6 cm FL (range: 52–71 cm FL, SD = 4.4); female adults (n = 244) averaged 83.3 FL (range: 72–102 cm FL, SD = 5.9).

Grilse comprised 14% (n = 62) of the 435 measured carcasses (Table 6). Nearly 25% (15) of the grilse were observed during the first week; 50% of all grilse was observed during the first three weeks (28 December 1998–13 January 1999) (Figure 9). Adults comprised 86% (n = 373) of the carcasses measured.

Sex Composition

Males comprised 35% (n = 129) and females comprised 65% (n = 244)(Table 7) of the fresh adult carcasses examined. Males also comprised 35% (n = 22) and females comprised 65% (n = 40) of the fresh grilse examined. Males comprised 35% (n = 151) of all fresh carcasses measured and females comprised 65% (n = 284).

The female to male ratio for adult spawners was nearly 1.9 to1 (244:129) (Table 7 and Figure 10). Females made up at least 57% of the adult population, except during the third week. The female to male ratio for grilse also was 1.9 to1. Most grilse (94%) were observed during the first third of the season (Figure 11).

Spawning Success

A total of 275 female carcasses was examined for egg retention (Table 8). Ninety-seven percent (n = 267) had completely spawned, 1% (n = 3) had only partially spawned, and 2% (n = 5) had not spawned.

Population Estimates

An adult escapement estimate of 7,467 adults was calculated from fresh carcass data using the adjusted Petersen formula described above (Table 9). The adult estimate was then divided by 0.86 (the portion of adults based on fresh carcass subsample) yielding a total population estimate of 8,683 (7,467 adult and 1,216 grilse).

An estimate of 8,236 adults was calculated using the Schaefer formula (Tables 10 and 11). In order to use the Schaefer formula, we grouped fresh carcass results from weeks 7–11 to account for weeks 8–11 when no tags were recovered. This adult estimate was also divided by 0.86 for a total escapement estimate of 9,577 late-fall-run spawners (includes 1,341 grilse).

The 1999 escapement of 8,683 (using Petersen formula) is less than the 1967–1992 average of 14,159 for the section of stream from Keswick Dam to Red Bluff Diversion Dam (RBDD) (Table 12 and Figure 12). The estimates for the 1967 through 1992 period were based on RBDD ladder counts. Changes in operation of RBDD have eliminated the opportunity to count late-fall run since 1992.

Table 3. Distribution of carcasses (adults and grilse) observed during the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1998–April 1999.

Week	Reach 1		Reach 2		Reach 3	
	M[1/]	C[2/]	M	C	M	C
1	167	17	95	23	93	17
2	145	15	45	19	16	2
3	92	18	57	28	16	8
4	93	24	34	10	13	3
5	101	18	42	19	29	3
6	35	33	42	43	102	32
7	29	19	16	2	38	15
8	2	1	9	2	1	5
9	11	5	30	8	9	3
10	14	4	10	3	8	7
11	8	2	6	2	6	1
12	28	10	23	15	4	11
13	23	19	27	34	14	6
14	20	7	16	7	8	10
15	9	3	5	6	1	0
16	17	7	4	2	2	0
17	0	10	0	11	0	5
18	0	11	0	4	0	2
Total	794	223	461	238	360	130

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.

Table 4. Size and sex statistics for fresh carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

Week	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
1	63	82.8	57–105	26	89.3	57–105	37	78.3	60–97
2	58	82.5	34–105	22	84.4	34–105	36	80.9	62–93
3	50	81.8	45–103	28	83.2	45–103	22	80.0	63–99
4	38	85.2	70–105	15	91.9	70–105	23	80.8	70–94
5	41	83.7	63–104	13	91.6	63–104	28	80.1	63–100
6	60	84.6	52–105	23	95.3	63–105	37	78.5	52–95
7	18	85.2	62–101	7	93.0	73–101	11	80.3	62–93
8	4	85.2	82–89	1	82.0	–	3	86.3	83–89
9	16	86.5	65–104	4	91.0	65–104	12	85.0	75–92
10	12	87.9	77–102	2	101.5	99–102	10	85.4	77–102
11	4	90.8	81–98	1	98.0	–	3	88.3	81–98
12	17	81.8	75–100	1	100.0	–	16	80.9	75–94
13	18	82.3	71–92	2	89.0	86–92	16	81.4	71–92
14	17	88.4	79–102	3	99.3	98–102	14	86.0	79–101
15	7	85.6	79–97	1	97.0	–	6	83.7	79–94
16	7	86.1	78–92	2	91.5	91–92	5	84.0	78–91
17	3	85.3	80–90	0	–	–	3	85.3	80–90
18	2	73.0	62–84	0	–	–	2	73.0	62–84
Total (mean)	435	(84.4)	34–105	151	(92.4)	34–105	284	(82.1)	52–102

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	40	244	22	129
Mean FL (cm)	66.6	83.3	63.3	94.0
Range FL (cm)	52–71	72–102	34–70	72–105
S D	4.4	5.9	9.1	8.3

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Adults		Grilse	
Week	Number	Percent	Number	Percent
1	48	76	15	24
2	48	83	10	17
3	39	78	11	22
4	35	92	3	8
5	31	76	10	24
6	51	85	9	15
7	17	94	1	6
8	4	100	0	0
9	15	94	1	6
10	12	100	0	0
11	4	100	0	0
12	17	100	0	0
13	17	94	1	6
14	17	100	0	0
15	7	100	0	0
16	7	100	0	0
17	3	100	0	0
18	1	50	1	50
Total(mean)	373	(86)	62	(14)

* Based on length-frequency distributions grilse are defined as $\leq$71 cm FL

Table 7. Sex composition of grilse and adults carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Adults				Grilse[a/]			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	20	42	28	58	6	40	9	60
2	17	35	31	65	5	50	5	50
3	21	54	18	46	7	64	4	36
4	14	40	21	60	1	33	2	67
5	12	39	19	61	1	10	9	90
6	22	43	29	57	1	11	8	89
7	7	41	10	59	0	–	1	100
8	1	25	3	75	0	–	0	–
9	3	20	12	80	1	100	0	0
10	2	17	10	83	0	–	0	–
11	1	25	3	75	0	–	0	–
12	1	6	16	94	0	–	0	–
13	2	12	15	88	0	0	1	100
14	3	18	14	82	0	–	0	–
15	1	14	6	86	0	–	0	–
16	2	29	5	71	0	–	0	–
17	0	0	3	100	0	–	0	–
18	0	0	1	100	0	0	1	100
Total (mean)	129	(35)	244	(65)	22	(35)	40	(65)

a/ based on length-frequency distributions, grilse are defined as ≤71 cm FL

Table 8. Summary of spawning completion (egg retention) determined from fresh female salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998–April 1999.

Week	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	37	36	36(100)	0(0)	0(0)
2	36	34	30(88)	0(0)	4(12)
3	22	22	21(95)	1(5)	0(0)
4	23	23	22(96)	0(0)	1(4)
5	28	28	28(100)	0(0)	0(0)
6	37	36	36(100)	0(0)	0(0)
7	11	11	11(100)	0(0)	0(0)
8	3	0	–	–	–
9	12	12	12(100)	0(0)	0(0)
10	10	10	9(90)	1(10)	0(0)
11	3	3	2(67)	1(33)	0(0)
12	16	16	16(100)	0(0)	0(0)
13	16	16	16(100)	0(0)	0(0)
14	14	14	14(100)	0(0)	0(0)
15	6	6	6(100)	0(0)	0(0)
16	5	3	3(100)	0(0)	0(0)
17	3	3	3(100)	0(0)	0(0)
18	2	2	2(100)	0(0)	0(0)
Total (mean)	284	275	267(93)	3(1)	5(2)

Table 9. Summary of tagging and recapture of fresh adult carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998–April 1999.

Week	Date	Number observed	Number tagged	Number recovered (Original tagging period)
1	Dec 28–30	373	66	–
2	Jan 4–6	227	54	24(1)
3	Jan 11–13	188	43	9(2), 6(1)
4	Jan 19–21	167	38	8(3),4(2),4(1)
5	Jan 26–28	191	40	1(4),2(3),1(2),1(1)
6	Feb 1–3	253	55	22(5), 5(4), 2(3),1(2)
7	Feb 9–11	102	18	6(6),1(3)
8	Feb 16–19	20	4	0
9	Feb 22–26	64	15	0
10	Mar 1–4	44	12	0
11	Mar 8–9	23	4	0
12	Mar 15–17	86	17	3(9)
13	Mar 22–24	118	18	9(12),1(10)
14	Mar 29–31	64	17	2(2)
15	Apr 5–7	24	7	1(14)
16	Apr 12–14	31	7	1(14)
17	Apr 19–21	26	0	1(16),2(15),1(13)
18	Apr 26–28	16		0
Totals		2,017	415	118

Table 10. Upper Sacramento River adult late-fall-run chinook salmon population estimate using the Schaefer model based on tagging fresh carcasses with all captured untagged carcasses removed, December 1998 – April 1999.

Recovery period$_{(j)}$	Tagging period $_{(i)}$												Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
	1	2	3	4	5	6	7–11[a/]	12	13	14	15	16			
1	24												24	624	26.00
2	6	9											15	203	13.53
3	4	4	8										16	183	11.44
4	1	1	2	1									5	196	39.20
5		1	2	5	22								30	283	9.43
6			1			6							7	260	37.14
7–11[a/]							3						3	89	29.67
12							1	9					10	128	12.80
13									2				2	66	33.00
14										1			1	25	25.00
15										1	0		1	32	32.00
16									1		2	1	4	30	7.50
17													0	16	0.00
18													0		0.00
$R_{(i)}$	35	15	13	6	22	6	4	9	3	2	2	1	(Tagged carcasses recovered)		
$T_{(i)}$	66	54	43	38	40	55	53	17	18	17	7	7	(Total carcasses tagged)		
$T_{(i)}/R_{(i)}$	1.83	3.60	3.31	6.33	1.82	9.17	13.2	1.89	6.00	8.50	3.50	7.00	(Ratio)		

a/ Tagging and recovery periods were lumped to account for weeks when no tags were recovered.

Table 11. Upper Sacramento River adult late-fall-run salmon population estimate using the Schaefer model based on tagging fresh carcasses with all the captured untagged carcasses removed, December 1998–April 1999.

Recovery period$_{(j)}$	Tagging period$_{(i)}$												
	1	2	3	4	5	6	7–11[a/]	12	13	14	15	16	Totals
1	1,177												1,177
2	153	438											591
3	86	165	303										554
4	74	141	259	248									722
5		34	62	299	377								772
6			123			2,043							2,166
7–11[a/]							1,179						1,179
12							170	218					388
13									396				396
14										213			213
15										272			272
16									45		53	53	151
17													0
18													0
Subtotals	1,190	778	747	547	377	2,043	1,349	218	441	485	53	53	8,581
Tags		-54	-43	-38	-40	-55	-53	-17	-18	-17	-7	-7	-345
										Populations estimate -			8,236

a/ Tagging and recovery periods were lumped to account for weeks when no tags were recovered.

Table 12. Summary of late-fall-run chinook salmon escapement estimates (adults and grilse) for the Sacramento River (Keswick Dam to RBDD) from 1956 through 1999. (Data provided by Frank Fisher, DFG, Red Bluff).

Year	Total	Year	Total
1967	37,208	1984	5,907
1968	34,733	1985	7,660
1969	37,178	1986	6,710
1970	19,190	1987	14,443
1971	14,323	1988	10,683
1972	31,553	1989	9,875
1973	22,204	1990	6,921
1974	6,445	1991	6,531
1975	16,663	1992	10,371
1976	15,280	1993	no est.
1977	9,090	1994	no est.
1978	8,880	1995	no est.
1979	8,740	1996	no est.
1980	7,747	1997	no est.
1981	1,597	1998	9,717[a/]
1982	1,141	1999	8,683[a/]
1983	13,274		

a/ Based on carcass counts.

Coded-wire-tag Recovery Data

Five fresh carcasses observed during the survey were marked with adipose fin clips. Four of the five marked fish possessed coded-wire tags (Table 13).

Table 13. Summary of coded-wire tags recovered from carcasses observed during the 1998–99 late-fall-run chinook salmon spawner escapement survey.

Tag #	Brood year	Sex	Length (cm)	Date recovered	River mile recovered
No tag		Female	45	1/11/99	298
054109	95	Female	77	1/26/99	296.5
054118	95	Male	100	1/26/99	296.5
054241	96	Female	62	2/1/99	297
053621*	94	Female	81	3/24/99	286

* Read four times to assure accuracy

CONCLUSIONS AND RECOMMENDATIONS

1. The numbers of carcasses observed per week may have been affected by high flows and low visibility. An increase in flow and reduction in water clarity during week 4 likely depressed carcass counts; in week 5 flow decreased and clarity increased resulting in increased carcass counts. Similarly in weeks 7 through 12, flows increased and clarity decreased resulting in reduced counts.

2. Law (1994) concluded the Petersen model consistently and substantially overestimated the total population compared to either the Schaefer or Jolly-Seber models. In our survey, the Petersen formula produced a lower estimate. The higher Schaefer estimate is likely due to our grouping the weeks when tag recoveries were absent. A low recovery rate applied to this grouping resulted in a high proportion of the Schaefer estimate occurring during these weeks (Tables 10 and 11).

ACKNOWLEDGMENTS

The California Department of Fish and Game recognizes the efforts of Chris Cox, Paul Divine, John Galos, Jordan McKay, Carrie Savage, Mike Spiker, and Jonathan Sutliff. Their efforts in the collection of field data are greatly appreciated. The data collection was funded by the FWS as a part of a cooperative agreement with the DFG as authorized by the CVPIA (P.L. 102-575).

LITERATURE CITED

Boydstun, L.B. 1994. Evaluation of the Schaefer and Jolly-Seber methods for the fall-run chinook salmon, *Oncorhynchus tshawytscha,* spawning run into Bogus Creek, Upper Klamath River, Calif. Fish & Game 80(1):1–13.

Law, P.M.W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif. Fish & Game 80(1):14–28.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dep of Environ., Fish. And Mar. Serv. Bull.191. 382 p.

Schaefer, M.B. 1951. Estimation of the size of animal population by marking experiments. USF&WS Bull. 52:189–203.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey: Lower American River, 1991–1992, Final report. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow and Habitat Evaluation Program.

Snider B., B. Reavis, and S. Hill. 1998. 1998 Upper Sacramento River late-fall-run chinook salmon escapement survey, September–December 1998. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Habitat Evaluation Program.

Snider B., B. Reavis, and S. Hill. 1999. 1998 Upper Sacramento River winter-run chinook salmon escapement survey, May–August 1998. Calif. Dept. Fish & Game, Water and Aquatic Habitat Conservation Branch, Stream Evaluation Program, Tech Rpt. 99-1.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

Snider, B. And K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall, 1993. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

APPENDIX

Appendix Table 1. Comparison of results from the 1998 and 1999 upper Sacramento River late-fall-run spawner survey.

Parameter	1998 survey	1999 survey
Survey dates	29 Dec 1997–1 May 1998	28 Dec1998–28 Apr 1999
No. of total carcasses	847	2,206
No. of fresh carcasses	182	450
No. of decayed carcasses	665	1,756
Tag recovery rate	9.2%	28.4%
Estimated population	9,717 (Petersen model)	8,683 (Petersen model)
Adult estimate	8,648	7,467
Grilse estimate	1,069	1,216
Adult female estimate	49%	56%
Adult male estimate	40%	30%
Grilse female estimate	7%	9%
Grilse male estimate	4%	5%
Female:male ratio adults	1.2:1	1.9:1
Size criterion (male)	Adult >70cm	Adult >71 cm
Size criterion (female)	Adult >70cm	Adult >71 cm
Spawning success (%)	93%	93%
Spatial distribution (Reach 1,2,3)	62%, 19%, 19%	46%, 32%, 22%
Temporal distribution(Jan, Feb, Mar, Apr)	97%, 2%, 0.3%, 0.7%	57%, 22%, 16%, 5%
Flow range	4,200–52,800 cfs	5,500–29,800 cfs
Temperature range	47–54° F	47–52° F
Visibility range	4–12 ft	5–10 ft

FIGURES

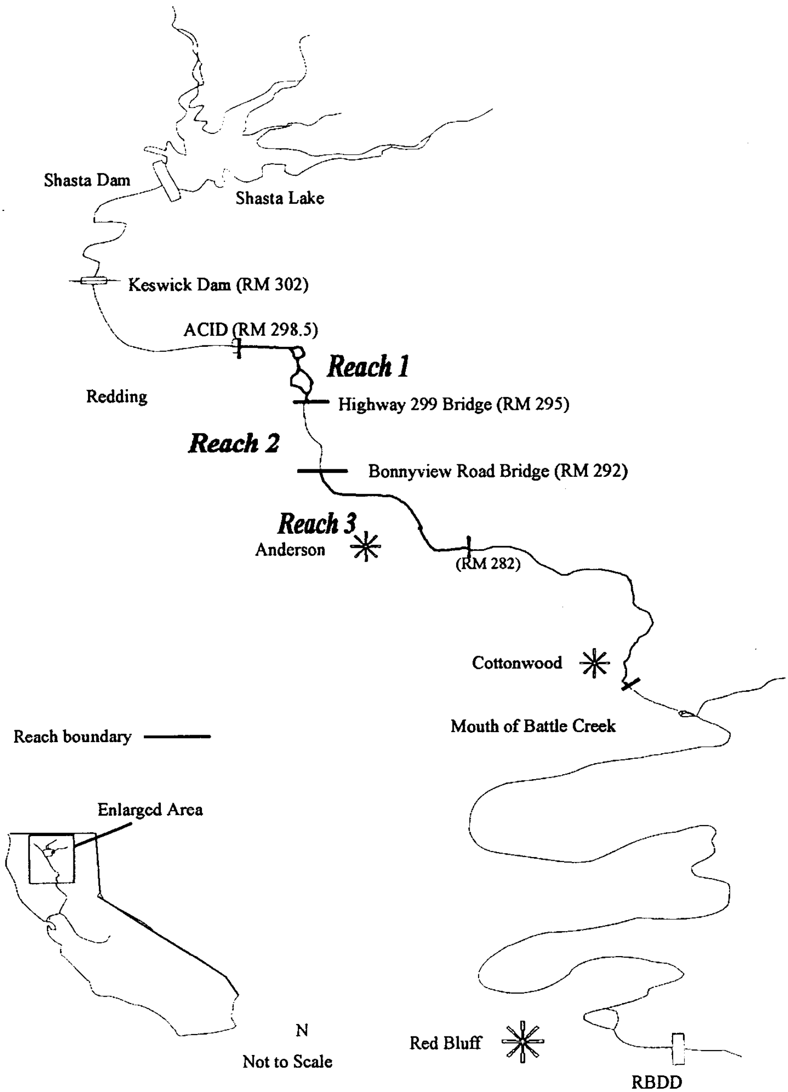


Figure 1. Locatoin of the reaches surveyed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

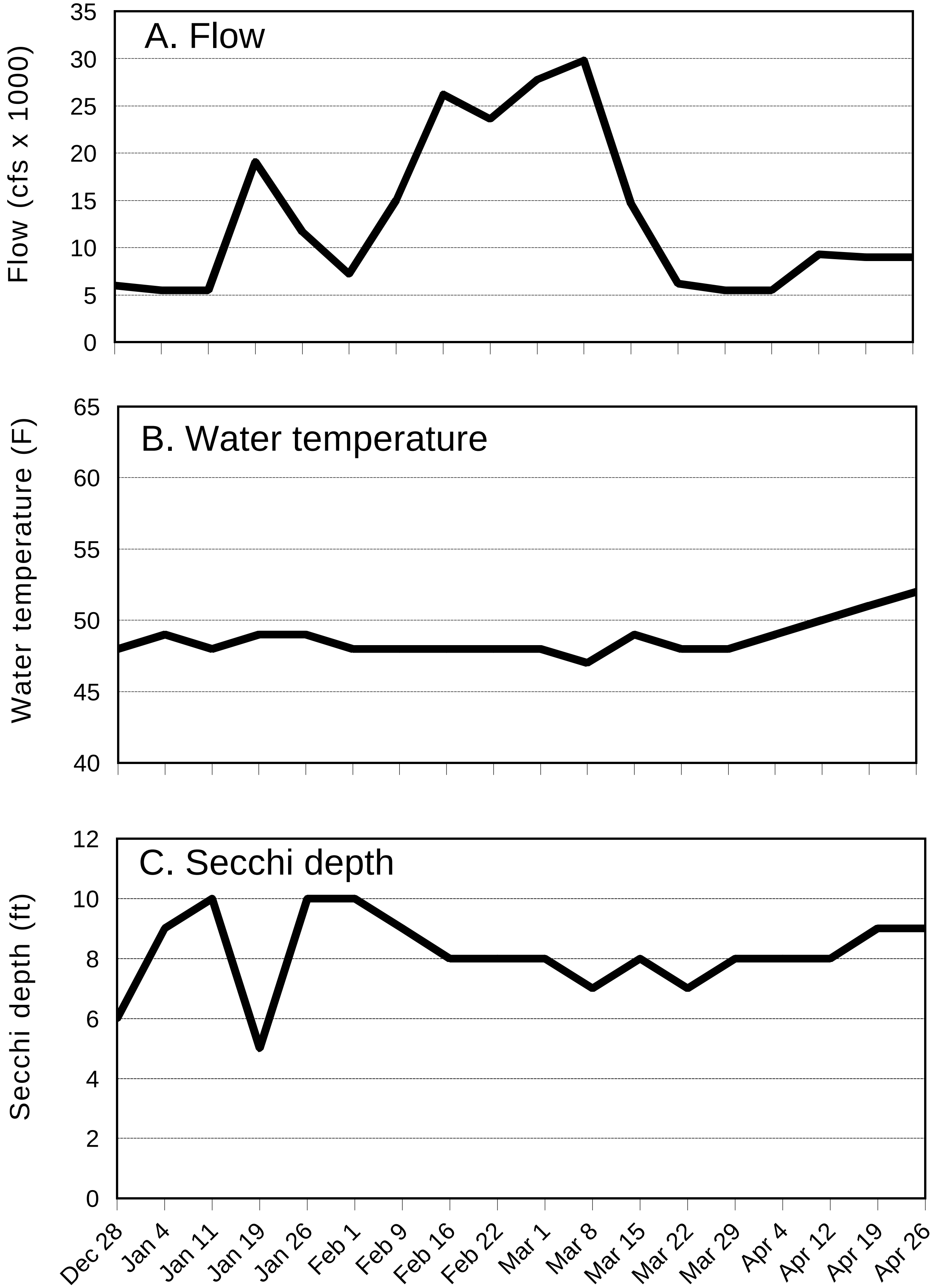


Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and secchi depth (C) during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

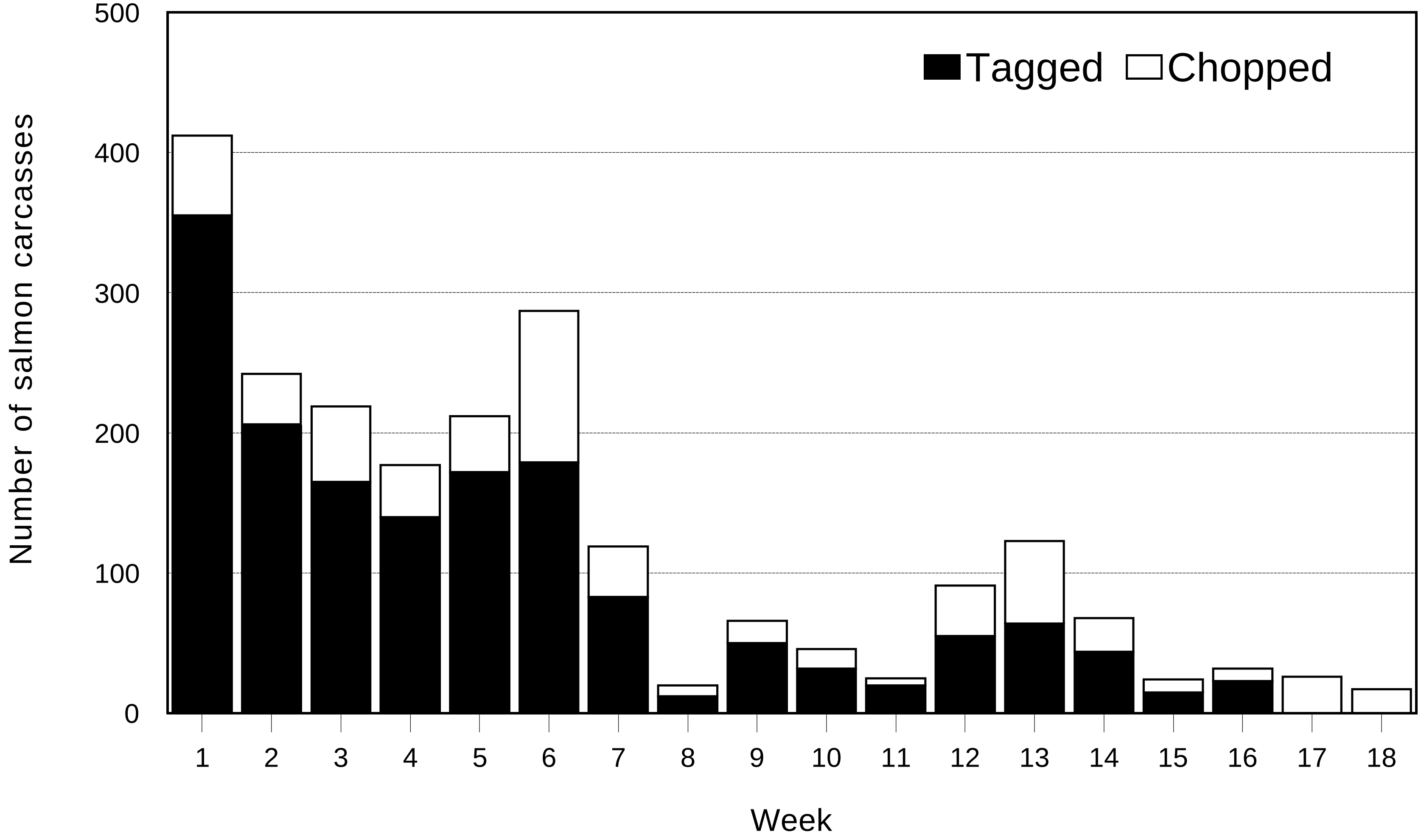


Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

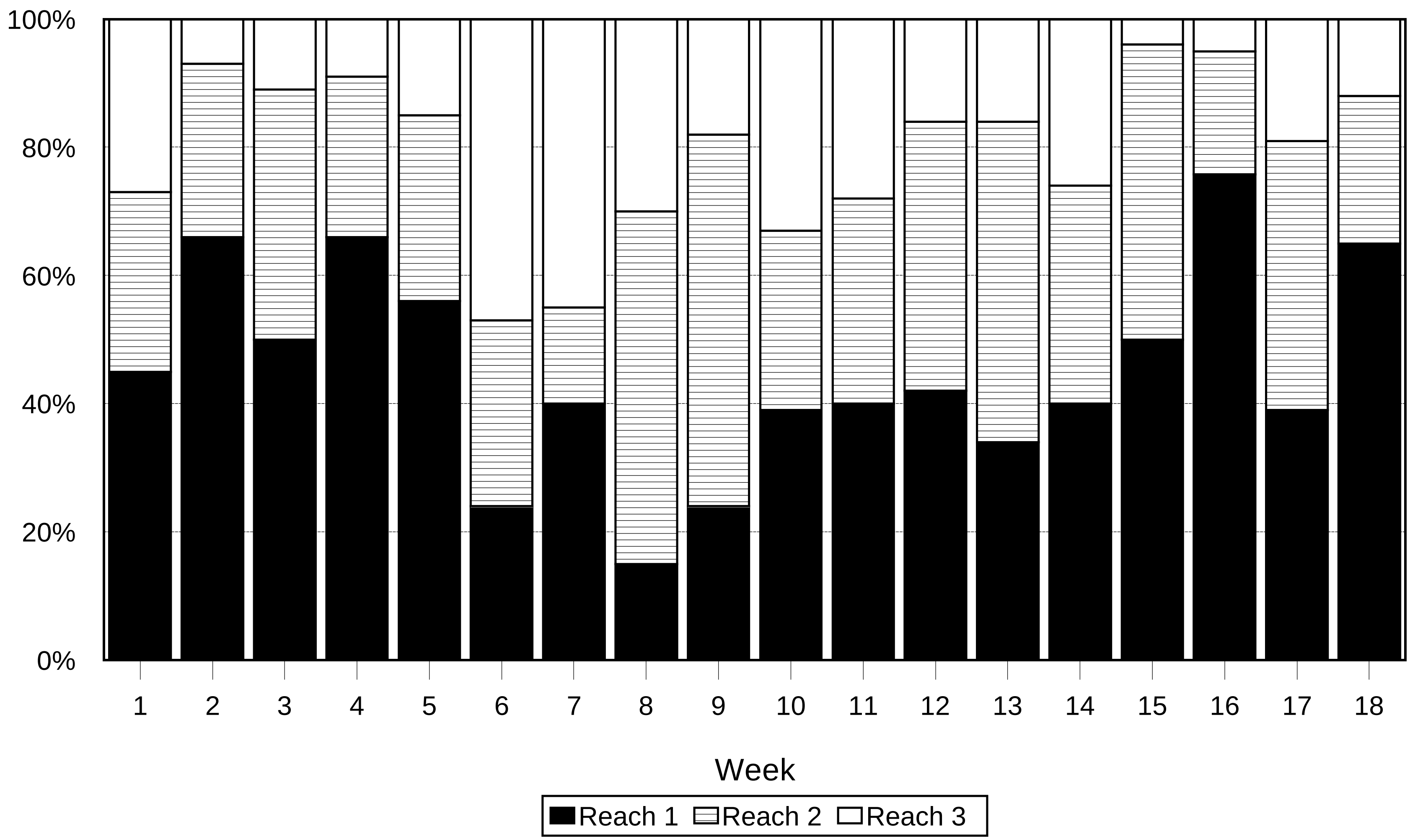


Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

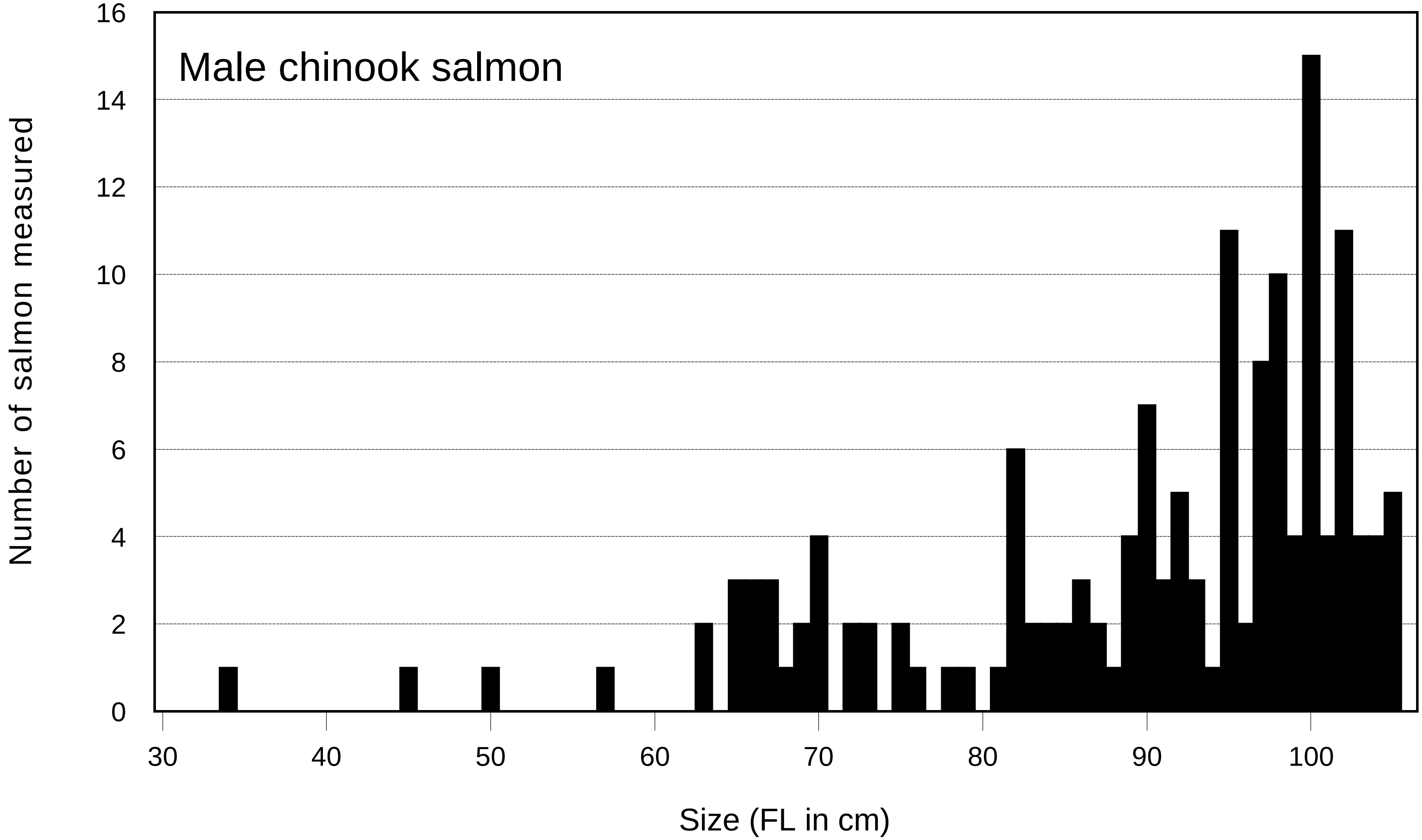


Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

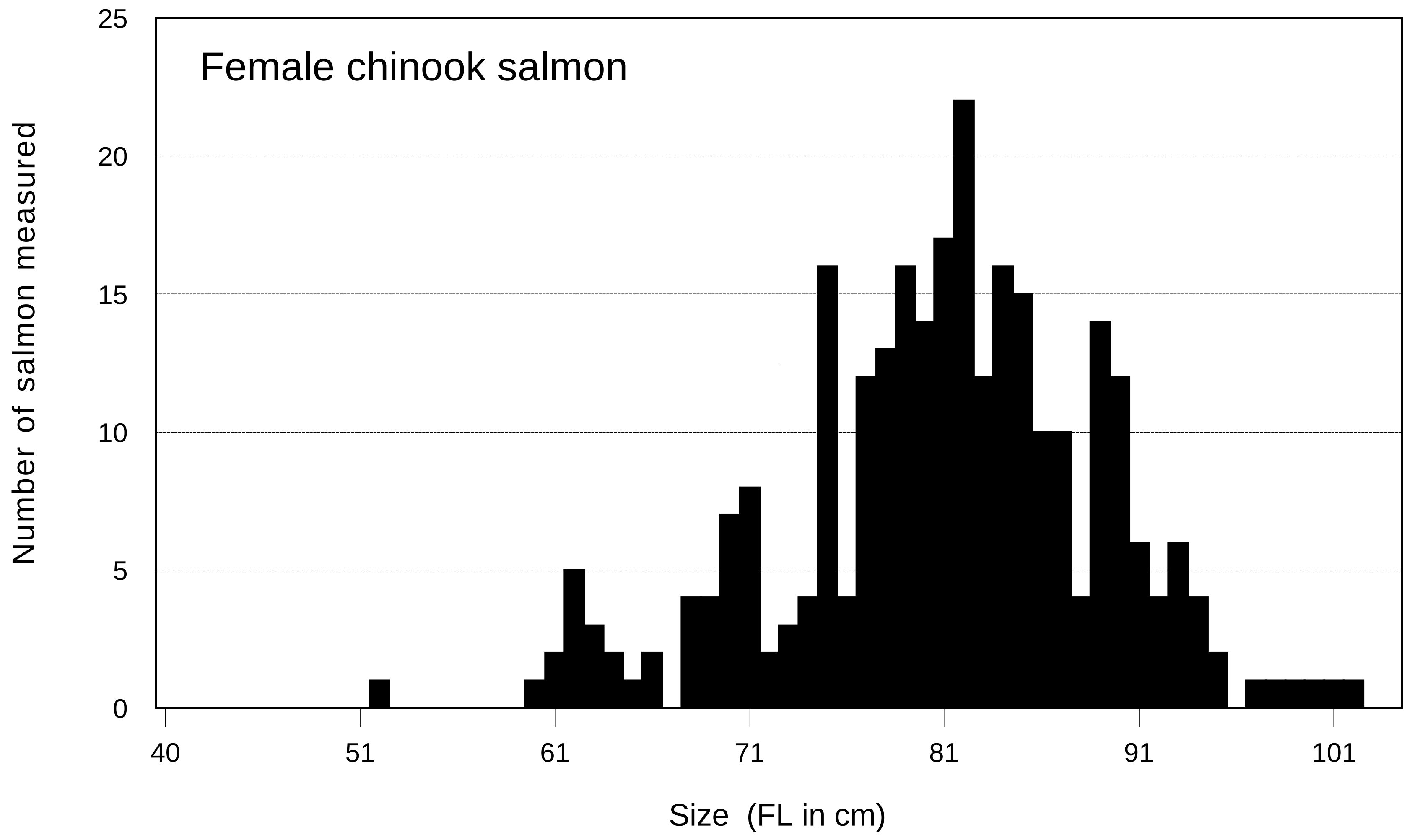


Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

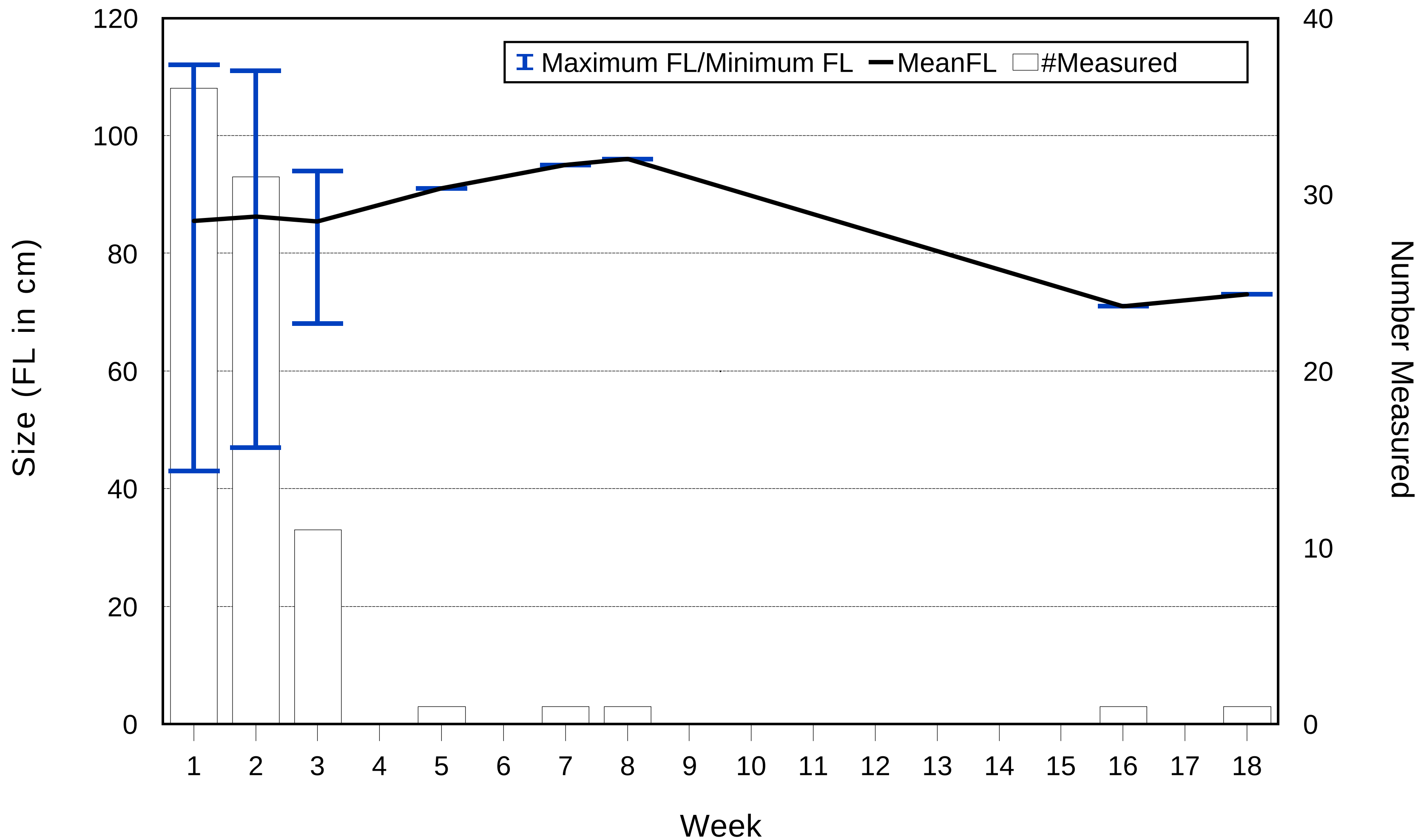


Figure 7. Mean weekly size, size range, and number of male chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

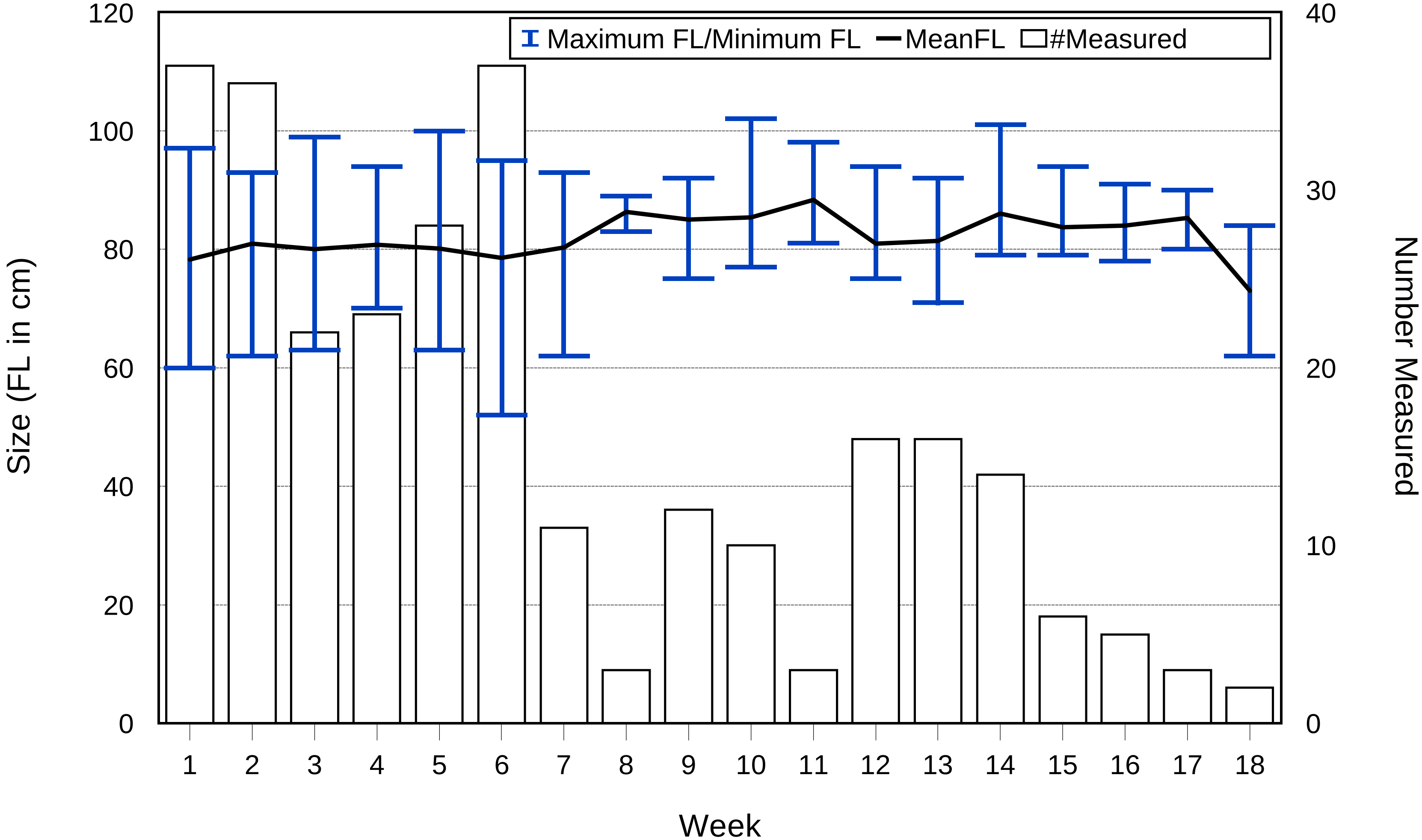


Figure 8. Mean weekly size, size range, and number of female chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

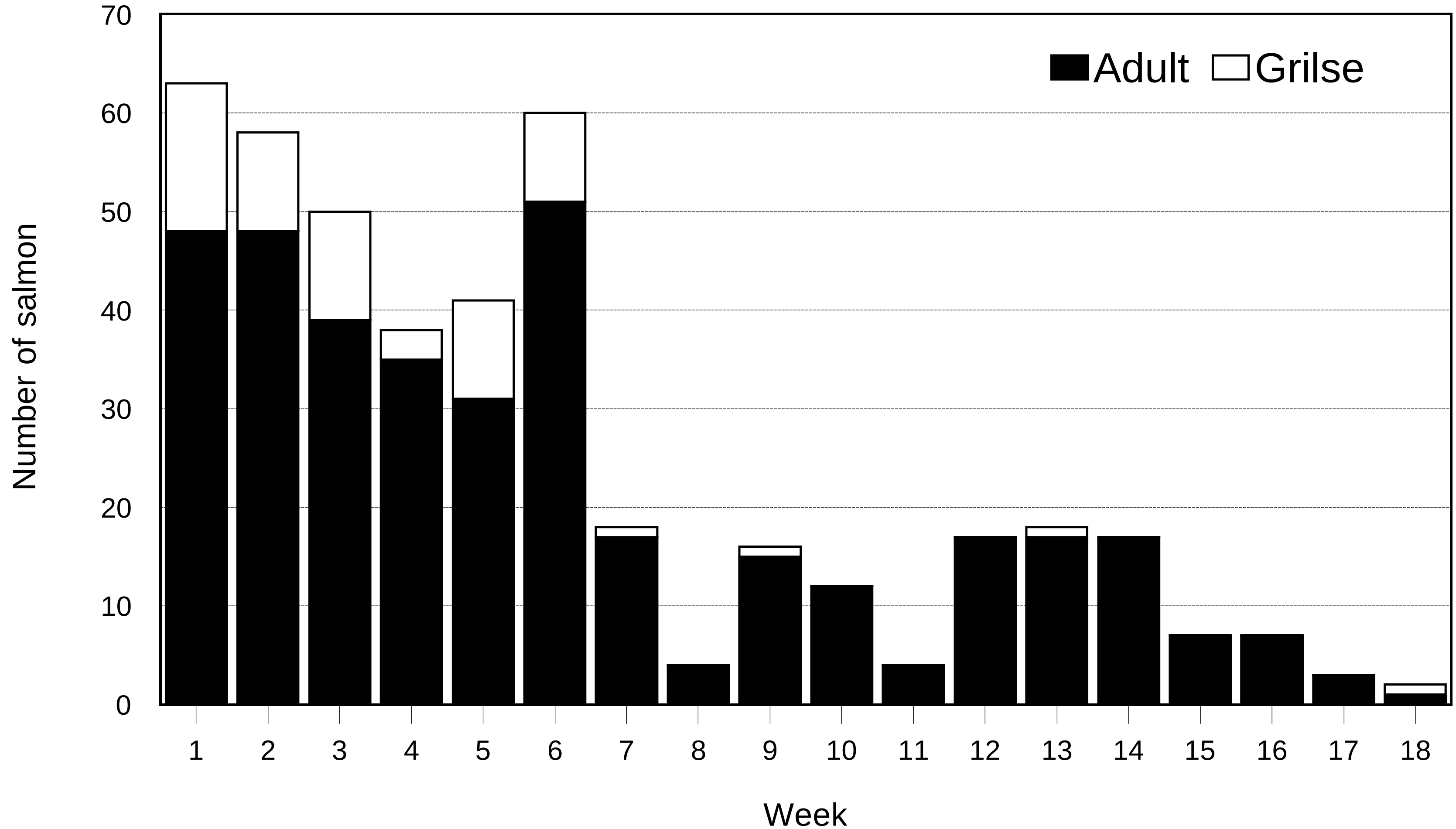


Figure 9. Weekly age compostion of chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

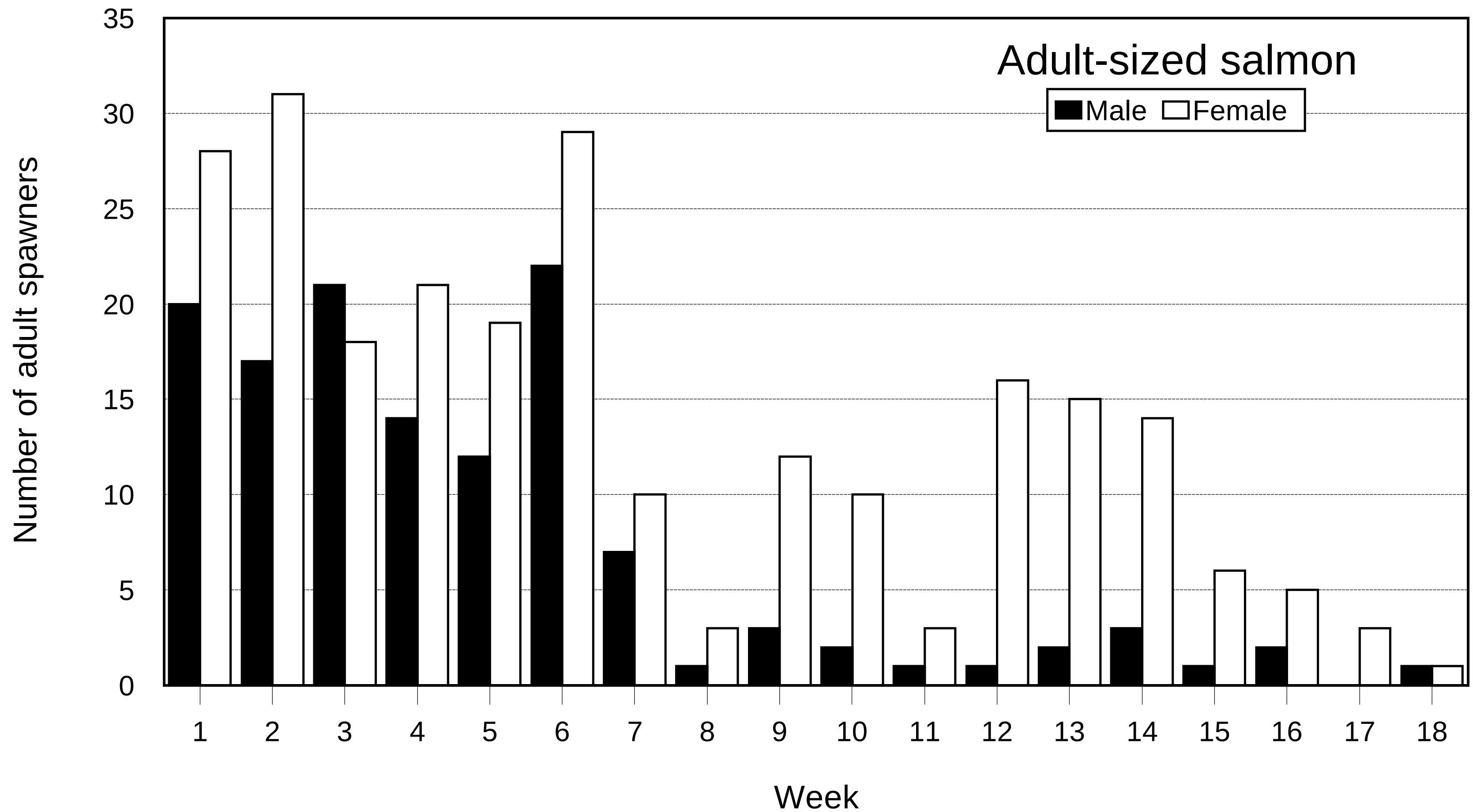


Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

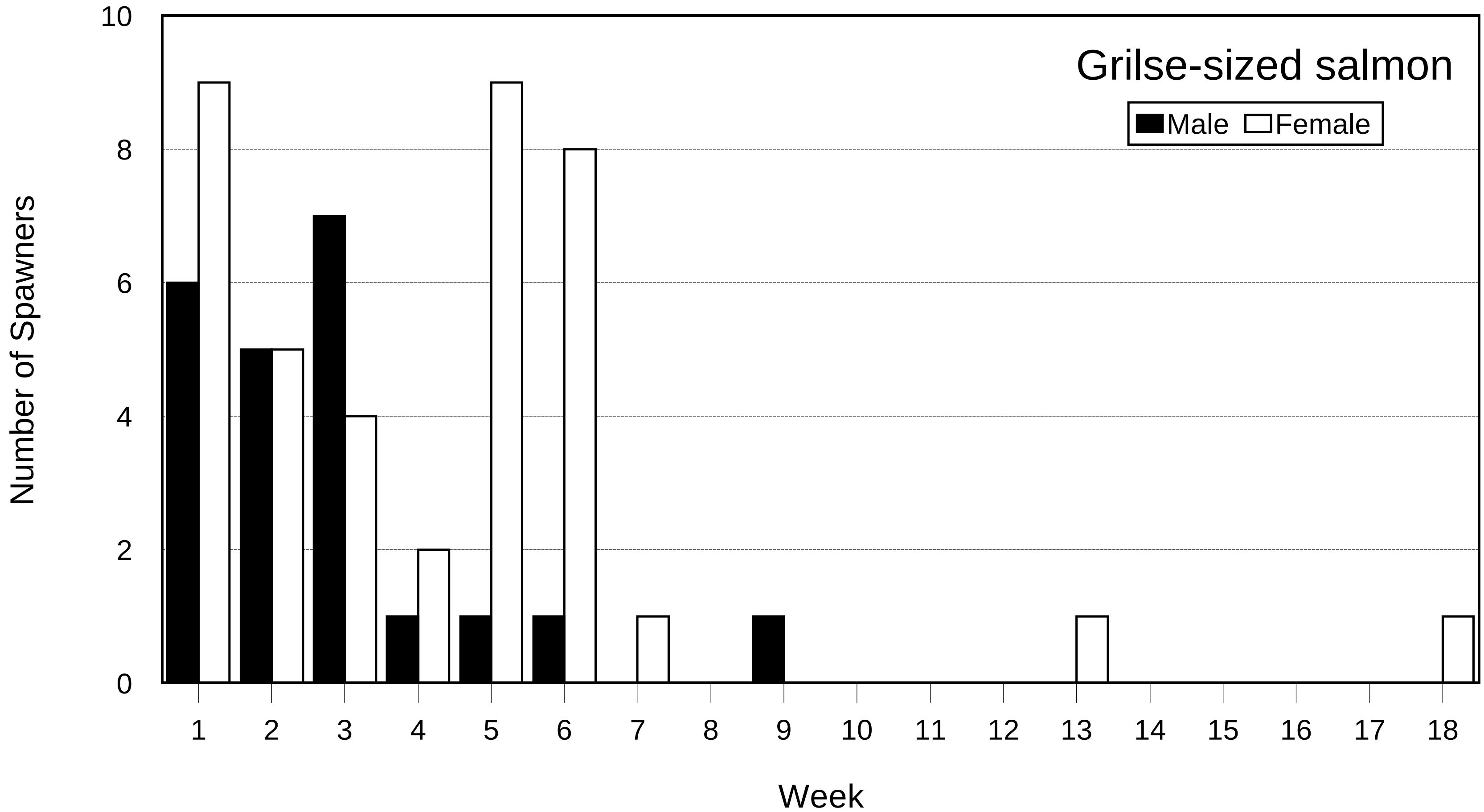


Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

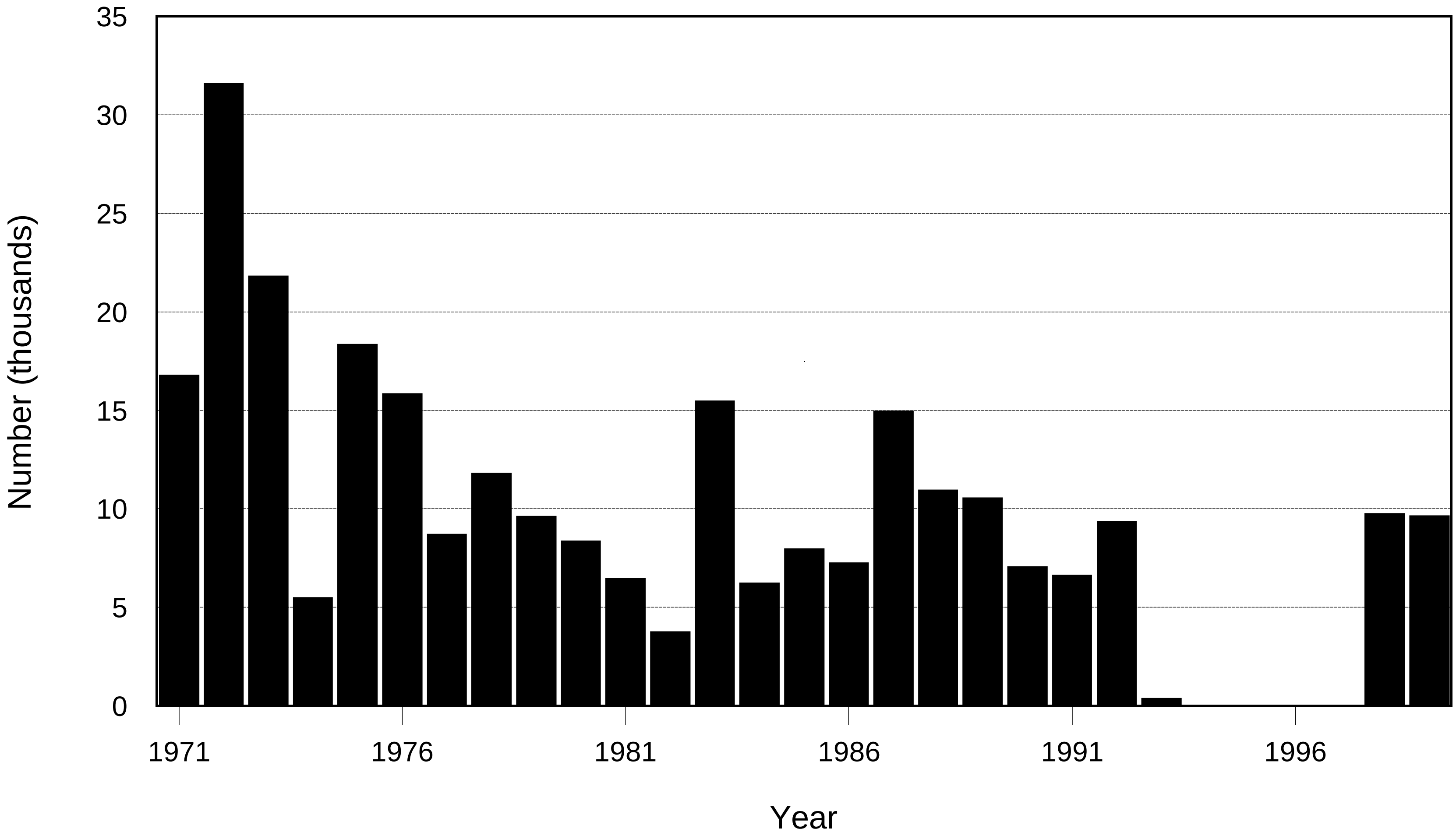


Figure 12. Summary of late-fall-run chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1971 - 1999).

APPENDIX V

Winter-run chinook salmon spawner survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Habitat Branch
Stream Evaluation Program

1999 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May–August 1999[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

January 2000

1/ This was a cooperative investigation with U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office and was supported by funding provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report No. 00-1

TABLE OF CONTENTS

SUMMARY

The California Department of Fish and Game's Stream Evaluation Program and the US Fish and Wildlife Service's Northern Central Valley Fish and Wildlife Office jointly conducted a winter-run chinook salmon, *Oncorhynchus tshawytscha,* escapement survey in the upper Sacramento River during spring–summer 1999 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. This was the fourth consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system. The survey was conducted from 5 May through 27 August 1999. It covered the uppermost 14 miles of the Sacramento River accessible to migrating salmon, from river mile 288 (RM 288) upstream to Keswick Dam (RM 302).

Flows ranged from 9,300 cubic feet per second (cfs) on 17–18 May to 13,700 cfs on 12–13 July. Secchi depths (water clarity) ranged from 5.8 ft (11–12 May 1999) to 10.7 ft (8–9 August 1999). Flow fluctuation was less and water clarity was greater than in past years providing more favorable survey conditions. Water temperature fluctuated between 50 $^{\circ}$F and 54 $^{\circ}$F (mode = 52 $^{\circ}$F) throughout the survey. The peak in fresh carcass observations occurred during mid to late June indicating that peak spawning was from early to mid June (2 weeks prior).

A total of 475 carcasses (212 fresh and 263 decayed) were collected; only measurements from fresh carcasses were used. Length frequency distributions were used to estimate the size distinguishing adults from grilse (<2-year-old salmon) by sex. Males >63 cm FL and females >59 cm FL were classified as adults. Using these criteria, 80.5% of the population were adults and 19.5% were grilse. Overall, 25.2% of all measured carcasses were male and 74.8% were female; 10.7% of the adults were male and 89.3% were female.

We checked 157 females for egg retention: 97% had completely spawned; 1 percent were partially spawned; and 2 percent were unspawned.

Four adipose-fin marked carcasses were collected. Coded-wire tag (CWT) data were obtained from two of these carcasses. The CWT data showed that both were 1995 brood year fish from Coleman National Fish Hatchery: one was a winter run and one a late-fall run.

The carcasses tag-and-recapture survey conducted to estimate spawner escapement resulted in a recovery rate of 22% for fresh adult carcasses (36 out of 161) and a 21% recovery rate for all carcasses. The Petersen formula applied to the fresh carcass data yielded an escapement estimate of 2,262 including 1,821 adults and 441 grilse. The estimated number of adult females was 1,626 (total female estimate = 1,691). The effective spawner population was 1,577.

In comparison, the 1999 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RM 243) was 3,208 (1,001 adults, 2,207 grilse). The adult female escapement estimate was 427, and the total female escapement was 982.

INTRODUCTION

A winter-run chinook salmon, *Oncorhynchus tshawytscha*, escapement survey was conducted in the upper Sacramento River during spring–summer 1999 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the forth consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon-habitat requirements in the Sacramento River system (Snider et al.1997, Snider et al. 1998 and Snider et al. 1999). A fundamental component of the investigation is the identification of salmon-habitat relationships at all life stages, including spawning for all salmon runs in the system. Also, since spawning habitat investigations can be influenced by both spawner abundance and habitat availability, it is important that spawner population surveys and habitat monitoring be conducted concurrently to distinguish the influences of these two factors on habitat use.

Escapement surveys conducted concurrently with redd surveys have been successfully used in the lower American River to identify relationships between spawning habitat availability and flow (Snider and McEwan 1992, Snider et al. 1993, Snider and Vyverberg 1995). The investigations on the lower American River strongly suggest that relationships among water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and habitat availability, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that spawner escapement surveys should be conducted on the upper Sacramento River.

The 1996 survey was the first attempt to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-and-recapture surveys have been routinely used to estimate escapement to Sacramento Valley tributary streams (e.g., American, Yuba, and Feather rivers and Battle Creek). This method was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974). Three models have been used by the California Department of Fish and Game (DFG) to estimate escapement from carcass mark-and-recapture data: the Petersen (Ricker 1975), Schaefer (1951), and Jolly-Seber (Seber 1982) models. The Petersen formula is the simplest but least accurate and has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller tributary streams (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modified Schaefer model has been used in “larger” Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. The Jolly-Seber model was first used in the Central Valley in 1988 to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers.

Evaluation of winter-run spawning in the Sacramento River is an integral part of an agreement between the DFG and the U.S. Fish and Wildlife Service’s (FWS), Central Valley Anadromous Fish Restoration Program to determine habitat requirements for anadromous salmonids. Studies being implemented by the DFG will provide the FWS with reliable scientific information for development of flow recommendations and satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B). The Sacramento River was selected for intensive fish-habitat investigations due to the significant influence the Central Valley Project has upon flow, temperature and ultimately fish habitat in the river. Furthermore, the upper Sacramento River is the only stream reach in the Central Valley that supports all four chinook salmon runs and steelhead. The exclusive occurrence of winter-run chinook salmon - a federally and state listed species - and the presence of rapidly disappearing Central Valley steelhead that were listed as threatened under the federal Endangered Species Act in March 1998, underscore the significance of habitat in this stream reach.

Results of the carcass survey may be used for comparison and possible augmentation of data collected on winter-run migration at the Red Bluff Diversion Dam (RBDD). Similarly, the survey could augment weekly winter-run-redd surveys. The FWS, Northern Central Valley Fish and Wildlife Office (NCVFWSO) and Coleman National Fish Hatchery (CNFH) could also use the results to evaluate their winter-run-escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996 and Croci and Hamelberg 1997).

Objectives

The objectives of the 1999 winter-run chinook salmon spawner escapement survey were:

- To estimate the in-river, winter-run chinook salmon population in the upper Sacramento River based on a carcass mark-recapture survey and augment estimates that are based on RBDD counts.

- To continue examination of the feasibility of using mark-recapture techniques (i.e., Petersen, Jolly-Seber, and Schaefer population models) to estimate winter-run escapement in the upper Sacramento River, and recommend future escapement estimating procedures.

- To obtain baseline information on spawning distribution (spatial and temporal), environmental conditions at the time of spawning, and the spawning population (size, age, and sex composition, and spawning success) in order to eventually identify winter-run spawning habitat requirements in the upper Sacramento River.

Background

Winter run are one of four chinook salmon runs present in California's Central Valley. The other three runs are fall, late-fall, and spring. Winter run generally leave the ocean and enter fresh water to begin their upstream migration from December through June. The peak of the run normally passes RBDD in March and April. Winter run typically spawn from mid-April through mid-August.

The earliest references to winter-run salmon have been summarized by Fisher (1993). In 1874, Livingston Stone noted winter run in the McCloud River, a tributary to the Sacramento River that presently drains into Shasta Lake. Winter-run status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Since Shasta Dam blocks winter run's access to most of its historic spawning habitat, they now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River (Figure 1). A small number of winter run spawn in some of the major upper Sacramento River tributary streams. Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, as threatened by the National Marine Fisheries Service (NMFS) in 1990, and then as endangered in 1994.

The NMFS (1996) has developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over 13 consecutive years is at least 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over 3 brood years. The assumed age structure is 50% 2-year olds, 44% 3-year olds, and 6% 4-year olds for males; and 89% 3-year olds and 11% 4-year olds for females. The population criteria also assume that annual escapement will be estimated with a precision of ±25%.

Since 1969, winter-run escapement estimates have been based upon counts of salmon using fishways that provide passage over RBDD. Counts can only be made when: the diversion is in operation, the gates are down, and all fish migrating above RBDD have to use the fishways located in the center and on the east and west ends of the dam. From 1969 through 1985, RBDD was typically operated throughout the entire winter-run migration period allowing a complete accounting of winter-run escapement. Although this dam hampers upstream migration when the gates are down and fish are migrating through the ladders, it provided an opportunity for fish migrating upstream to be accurately counted. Beginning in 1986, the operation of RBDD was modified to improve winter-run migration. With the modified operation, the gates are typically raised from mid-September through mid-May the following year allowing the unimpeded upstream passage of most winter run. The diversion and fishways now only operate during the mid-May through mid-September period which typically included only a small portion of winter-run migration when season long counts were possible (1969–1985) (Figure 1). Annual escapement is now estimated by expanding the abbreviated season-long count, assuming it is proportionate to historic, complete season-long counts. The proportion used to divide the abbreviated count represents the fraction of the total population that passed RBDD (when complete season-long counts were made) based on the date that the diversion is placed in operation.

The method of counting fish through the fishways is essentially the same as when counts covered the entire migration (pre-1986). The procedures employed to count salmon using the RBDD fishways include a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings of fish using the center fishway. Fish using the east and west ladders are counted directly through viewing facilities from 0600 to 2000 h each day, 7 days per week. Fish using the center ladder are counted by video taping fish passage from 0600 to 2000 h each day 7 days per week. The video tapes are reviewed to identify and count fish that had passed. Once a week, the DFG determines night passage at the east and west ladders by extending the direct counts from 2000 to 2200 h and then video taping passage from 2200 to 0600 h the next morning to identify and count fish that had passed. The single night count is used to determine a correction factor to account for night passage for all other nights of the week. The DFG also operates a fish trap located in the east-bank fish ladder. The trap is usually operated 7 days a week through July, then 5 days a week through mid-September, from 0600 to 1500 h, when water temperatures are $\leq 60\ ^{o}F$. Trapped fish are identified to species or, if a salmon, to run. Fish are measured and checked for marks (e.g., adipose-fin clips).

METHODS

The NCVFWSO and the DFG's Stream Evaluation Program jointly conducted a carcass mark-and-recapture survey during 1999 to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 5 May through 27 August 1999. Methods were similar to those used during the 1998 winter-run-escapement survey (Snider et al. 1998).

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 2), which is considered the primary spawning area for winter run in the upper Sacramento River. After observing a low tag recovery rate (15% for all tagged carcasses) and noting over 90% of the winter-run spawning activity occurred in the upper 14 miles of the 31-mile section surveyed in 1996, we shortened the study area to this 14-mile section and increased our survey frequency starting in 1997. The new study area was divided into two 7-mile reaches and each of these reaches was surveyed an average of 2.5 times per week. This change was intended to provide an adequate coverage of most of the area used by winter run to spawn and increase our tag recovery rate which in turn would provide a more accurate escapement estimate. This practice was continued in 1999.

The study section was divided into the following two reaches:

1. Keswick Dam to Cypress Street Bridge - RM 302 to RM 295, and

2. Cypress Street Bridge to Redding Water Treatment Plant - RM 295 to RM 288.

The upper reach was surveyed on the first day and the lower reach on the second day of each 2-day survey period. This cycle was repeated following a one-day break. Most of the survey effort was conducted by boat (two boats and two observers per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. There were several short stretches of river that were surveyed on foot. Survey effort was primarily concentrated in areas where carcasses were known to collect. Most observed carcasses were collected using a gaff or gig, then sexed, measured and tagged, as described below.

Flow measurements from the Keswick gauge were obtained from the U.S. Geological Survey. Water temperatures and Secchi disk (water clarity) readings were measured daily by the survey crew.

Population Estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Most collected carcasses were tagged except those in an advanced state of decay. Carcasses not tagged were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. Carcasses were tagged by attaching a small colored plastic ribbon to the upper or lower jaw with a hog ring. The tag color was used to identify the survey period that the carcass was tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw and decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to accommodate the various population estimators. All tagged carcasses were returned to flowing water near where they were collected in an attempt to simulate "natural" carcass dispersion. Recovered, previously tagged carcasses were examined for tag color, location of tag (upper or lower jaw), and age (based on size). The pertinent data were recorded and the carcass was chopped.

Based on DFG protocol, results from fresh carcass data are normally used to calculate an escapement estimate using the Schaefer model, and results from both fresh and decayed data are used to calculate an estimate using the Jolly-Seber model. The Jolly-Seber (Seber 1982) and Schaefer (1951) models were not used to calculate the 1999 estimates since they require that there be tag recoveries from all tagging periods (about one-third of the periods had no tag recoveries). Instead, the Petersen formula (Ricker 1975) was used to calculate estimates using both sets of data (fresh and combined fresh and decayed) .

The adjusted Petersen formula (Ricker 1975) used to calculate the escapement estimate is as follows:

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where:

N	=	population size,
M	=	total number of carcasses tagged,
C	=	total number of examined, and
R	=	total recaptures of tagged carcasses in the *j*th recovery period.

Size/age Distribution and Sex Composition

Fork length (FL), sex, and date of collection were recorded for most measurable carcasses. Some carcasses were too deteriorated to allow accurate measurements. The length-frequency distribution of each sex was used to define the length separating adults (>2-years old) and grilse (2-year olds). Fresh carcasses measurements are more accurate and were used to develop length-frequency relationships and sex ratios.

Spawning Success

All measurable female carcasses were checked for egg retention. Females were classified as spent if few eggs remained, as partially spent if a substantial amount (50% or more) of eggs still remained in the body cavity, and unspent if they appeared to be completely unspawned.

Temporal Distribution

Fresh carcasses were assumed to become available to sampling within 2 weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total numbers of fresh carcasses observed in both reaches were used to describe temporal spawning distribution.

Spatial Distribution

The total number of fresh carcasses observed in each survey reach was used to define season-long geographic distribution of spawning activity. Flow likely carried some carcasses from the upstream reach, where spawning occurred, to the downstream reach, where recovery occurred, potentially biasing the spatial distribution of spawning toward the downstream reach.

Hatchery-produced Winter-run Chinook Salmon

Carcasses were also checked for adipose-fin clips, indicating the fish was of hatchery origin and possessed a coded-wire tag (CWT). Heads were collected from clipped carcasses and the CWTs were later extracted and read to identify the hatchery origin of the fish.

Radio-tagging Study

During the course of the carcass survey, we conducted a pilot study to determine if we could monitor carcass dispersion using radio tags. Tag recovery rates during the past three winter-run escapement surveys have been low relative to similar surveys on fall-run chinook salmon (Snider et al. 1999a, 199b). The primary differences in sampling conditions between the two survey periods are higher flows and lower visibility. (Another major difference is the size of the spawner populations, thus the number of carcasses available for tag-and-recovery surveys). Tracking carcasses using radio tags could show if the higher flows sweep tagged carcasses out of the survey area before they can be observed during the recovery surveys, and if reduced visibility impedes the ability to find carcasses otherwise visible during the fall surveys.

Thirteen adult carcasses that were tagged with hog rings were also fitted with radio tags during the 12–13 July survey period. These carcasses were released back into running water in the same manner that tagged carcasses are normally released during escapement surveys. Carcasses were tagged in about the proportion to their relative abundance in the two reaches. All tags had distinct signals to allow tracking individual carcasses.

Two radio-tagged carcasses were released at each of the following river miles (RM): 301, 298, 296.5, 296, 295 and 294. One radio-tagged carcass was released at RM 300 upstream of ACID dam. Carcasses were tagged then released in the same general area they were first observed.

A monitoring station was set up at the lower end (RM 288) of the study section to detect any radio-tagged carcass drifting out of the survey reach. This receiver unit was operated around the clock from 12:00 a.m. on 12 July to 11:00 a.m. on 16 July.

On 15 July, the section of stream from ACID dam (RM 298.5) to the monitoring station (RM 288) was surveyed from a boat using a another receiver unit and antenna in an attempt to precisely locate radio-tagged carcasses remaining in the survey reach. The section of river from Keswick Dam (RM 302) downstream to ACID dam was surveyed from a boat on July 20, and the section downstream of ACID dam was surveyed a second time on July 21. After detecting a radio tag, the crew then determined if the tag was “recoverable” (i.e., could be observed by the carcass survey crew).

RESULTS

General

A total of 212 fresh and 263 decayed carcasses were observed during the 38 survey periods (Table 1). Mean flow ranged from 9,300 to 13,700 cfs (Figure 3). Mean temperature ranged from 50 ^{o}F to 54 ^{o}F (mode = 52 ^{o}F). Secchi depth readings ranged from 5.8 to 10.7 ft and generally increased as the survey season progressed.

Population Estimates

The Petersen (Ricker 1975) formula was used to estimate escapement. The Schaefer and Jolly-Seber models were not used since there were no recoveries made from about one-third of the released tag groups. A total of 161 fresh adult carcasses were tagged and 36 (22%) were subsequently recovered (Table 2). The adult tag recovery rate for decayed and fresh carcasses combined was 21%.

The Petersen formula was applied using the season totals for both fresh adult carcasses and for all (fresh and decayed) adult carcasses. The fresh carcass data yielded an estimate of 1,821 adults. Assuming adults comprised 80.5% of the population, (based on length-frequency data results described below), the total population estimate was 2,262 salmon, including 441 grilse. The second estimate of adults using data from all tagged carcasses yielded a total population estimate of 2,493 (2,007 adults and 586 grilse). Based on Law's (1994) analysis, the estimate based on fresh carcass data is more accurate.

Size/age Distribution and Sex Composition

A total of 210 fresh carcasses was measured (Table 3). Mean FL was 67.3 cm (range: 45–105 cm FL). Male salmon (n = 53) averaged 64.5 cm FL (range: 46–105 cm FL) (Figure 4). Female salmon (n = 157) averaged 68.1 cm FL (range: 45–91 cm FL). The largest fish were observed during May (Figure 4). The monthly mean size ranged from 58.5 cm FL in July to 80.9 FL in May for males, and from 63.7 cm FL in August to 72.0 cm FL in May for females.

Length-frequency distributions were used to define a general size criteria to distinguish grilse (2-year-old salmon) from adults (>2-year-old salmon) for both sexes (Table 4 and Figure 5). The male and female length frequency distributions were quite different (Table 4 and Figure 5). About 96% of the females were grouped in a normal distribution (Figure 5a) that ranged from 66 to 91 cm FL with a mode of 66 cm FL. These fish were considered 3-year old fish. Females >59 cm FL were considered adults based upon the location of the break between the tail of this distribution and the few fish that were to the left. The male distribution was skewed with about 85% of the males ranging from 45 to 58 cm FL (Figure 5b). Based upon an apparent break in the distribution between 63 and 66 cm FL, male adults were defined as salmon >63 cm FL. We

Table 1. Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (°F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
1	May 5–6	10,500	52	9.0	4	11
2	May 8–9	11,000	53	8.4	0	3
3	May 11–12	11,000	52	5.8	4	6
4	May 14–15	10,700	52	7.1	2	2
5	May 17–18	9,300	52	7.7	5	2
6	May 20–21	9,600	53	7.8	0	2
7	May 23–24	10,100	53	6.9	3	5
8	May 26–27	10,800	50	8.2	8	2
9	May 29–30	11,400	50	7.8	3	4
10	June 1–2	11,000	50	8.1	5	7
11	June 4–5	10,800	52	6.8	10	12
12	June 7–8	10,500	52	8.2	15	6
13	June 10–11	10,500	52	10.2	8	6
14	June 13–14	10,500	52	9.4	5	8
15	June 16–17,	11,000	52	9.6	17	5
16	June 19–20	11,800	50	9.0	8	6
17	June 22–23	12,400	52	10.4	16	12
18	June 25–26	13,000	52	8.9	14	10
19	June 28–29	13,500	52	8.8	10	9
20	July 2–3	13,000	53	9.9	5	11
21	July 6–7	13,000	52	10.4	8	16
22	July 9–10	13,000[4/]	53	9.7	5	15
23	July 12–13	13,700	52	8.6	13	12
24	July 15–16	13,500	54	9.6	6	11
25	July 18–19	13,500	52	9.6	7	13

Table 1 (cont.)

Survey period	Dates	Mean flow (cfs)1/	Mean water temperature (°F)2/	Mean Secchi depth (ft)	Carcasses count3/	
					Fresh	Decayed
26	July 21–22	13,000	52	9.8	8	7
27	July 24–25	13,000	53	10.1	5	9
28	July 27–28	13,000	53	10.0	3	4
29	July 30–31	12,900	53	8.5	3	6
30	August 2–3	13,000	54	10.4	3	4
31	August 5–6	12,000 4/	54	10.0	2	5
32	August 8–9	11,000	54	10.7	2	4
33	August 11–12	10,600	53	9.9	1	10
34	August 14–15	9,800	52	10.0	1	3
35	August 17–18	9,500	52	8.2	0	6
36	August 20–21	9,500	52	8.8	1	2
37	August 23–24	9,500	52	9.2	1	4
38	August 26–27	9,500	51	9.2	1	3
				Totals	212	263

1/ Mean flow at Keswick Dam during survey period as measured by U.S. Geological Survey.
2/ Mean water temperature measured each day by survey crew.
3/ Includes grilse and adults; does not include tag recoveries.
4/ No flow measurement recorded for 9 July and 6 August 1999.

Table 2. Summary for each tagging period of number of carcasses observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during the 1999 upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	May 5–6	14	1	3	1	0
2	May 8–9	3	0	0	0	0
3	May 11–12	9	1	3	1	0
4	May 14–15	4	0	2	0	0[1,(3)-grilse]
5	May 17–18	6	1	5	0	1(4)
6	May 20–21	2	0	0	0	3(5)
7	May 23–24	8	0	3	0	0
8	May 26–27	9	1	7	1	0
9	May 29–30	7	0	3	0	1(8),1(7)
10	June 1–2	11	1	4	1	1(9)
11	June 4–5	21	1	10	0	1(10)
12	June 7–8	17	4	12	3	2(11),1(8)
13	June 10–11	13	1	7	1	2(12),1(11)
14	June 13–14	11	2	3	2	1(12)
15	June 16–17	20	2	16	1	2(14)
16	June 19–20	11	3	7	1	[1(15)-grilse]
17	June 22–23	26	2	15	1	2(16),1(14),1(12),1(10)
18	June 25–26	20	4	12	2	1(15),1(13),1(12)
19	June 28–29	14	5	7	3	1(17)
20	July 2–3	12	4	4	1	0
21	July 6–7	18	6	3	5	1(18)
22	July 9–10	9	11	1	4	0
23	July 12–13	19	6	10	3	0
24	July 15–16	16	1	5	1	1(23)
25	July 18–19	13	7	3	4	0

Table 2 (cont).

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
26	July 21–22	11	4	5	3	1(22)
27	July 24–25	11	3	3	2	1(23),1(22)
28	July 27–28	6	1	2	1	0
29	July 30–31	4	5	1	2	0
30	August 2–3	5	2	2	1	1(27)
31	August 5–6	4	3	1	1	1(29),1(27)
32	August 8–9	4	2	1	1	0
33	August 11–12	5	6	0	1	1(32),1(30)
34	August 14–15	3	1	1	0	0
35	August 17–18	4	2	0	0	0
36	August 20–21	2	1	0	0	0
37	August 23–24	4	1	0	0	0
38	August 26–27	3	1	0	0	0
	Totals	377	98	161	48	36 adults and 2 grilse

Table 3. Size and sex statistics for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, May – August 1999.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Month	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
May	29	74.8	52–105	9	80.9	52–105	20	72.0	60–90
June	108	67.5	45–91	20	63.0	48–82	88	68.6	45–91
July	63	63.4	46–84	21	58.5	46–84	42	65.9	53–84
August	10	64.5	56–79	3	63.3	58–79	7	63.7	56–78
Totals (mean)	210	(67.3)	45–105	53	(64.5)	46–105	157	(68.1)	45–91

Table 4. Summary of adult and grilse size and number by sex for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, May – August 1999.

	Female		Male	
	Grilse*	Adults	Grilse*	Adults
Total measured	6	151	35	18
Mean	54.3	68.8	55.4	82.1
Range FL (cm)	45–58	60–91	46–63	66–105
Standard deviation	4.9	6.1	4.5	12.0

* Grilse were defined as females ≤ 59 cm FL and males as ≤ 63 cm FL..

plan to verify the age/length relationship for the 1999 spawner population using scales and otoliths taken from most measured carcasses.

Male grilse averaged 55.4 cm FL (SD = 4.5; range: 46–63 cm FL) while female grilse averaged 54.3 cm FL (SD = 4.9; range: 45–58 cm FL) (Table 4). Adult males averaged 82.1 cm FL (SD = 12.0; range: 66–105 cm FL). Female adults averaged 68.8 cm FL (SD = 6.1; range 60–91 cm FL).

Adults comprised 80.5% (n = 169) of the population (measured carcasses) and grilse comprised 19.5% (n = 41) (Table 5). The proportion of grilse in the population increased from 10% in May to 40% in August.

The grilse population was comprised of 85% males (n = 35) and 15% females (n = 6) (Table 6). The adult population comprised 89% (n = 151) females and 11% (n = 18) males. The ratio of male to female for adult spawners was 1 to 8.4. The overall sex ratio, including grilse, was 1 to 3.0.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, May – August 1999.

Survey period	Adults		Grilse	
	Number	%	Number	%
May	26	90	3	10
June	94	87	14	13
July	43	68	20	32
August	6	60	4	40
Totals (Mean)	169	(80.5)	41	(19.5)

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, May – August 1999.

	Adults				Grilse			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	6	23	20	77	3	100	0	0
June	7	7	87	93	13	93	1	7
July	4	9	39	91	17	85	3	15
August	1	14	5	86	2	50	2	50
Totals (mean)	18	(11)	151	(89)	35	(85)	6	(15)

Spawning Success

Ninety-seven percent (n = 147) of the 151 fresh, adult female carcasses examined for egg retention had completely spawned. One percent (n = 1) had partially spawned, and 2.6% (n = 4) had not spawned. One of six grilse-sized females checked for spawning success was unspawned (83.3% success). The unspawned female grilse was 45 cm FL, the smallest salmon measured.

There was one unspawned female observed in May, two in June (1 adult and 1 grilse), and one in August. One partially spawned female was observed in June.

Temporal Distribution

Fresh carcasses were observed from survey period 1 (5–6 May) through survey period 38 (26–27 August) (Table 1, Figures 6 and 7). Seventy percent of the fresh carcasses were observed between 4 June and 13 July with the maximum occurring 17–18 June. Assuming that fresh carcasses become available for observation approximately 2 weeks after spawning, spawning occurred from late April into mid-August and peak spawning occurred during early June.

Spatial Distribution

Seventy-three percent (n = 154) of the fresh carcasses were observed in Reach 1 and 27% (n = 58) in Reach 2 (Table 7). For decayed carcasses, 58% (n = 152) were observed in Reach 1 and 42% (n = 111) in Reach 2. The ratio of fresh to decayed carcasses was 1 to 1 in Reach 1 and 1 to 1.9 in Reach 2.

Hatchery-produced Winter-run Chinook Salmon

Four adipose-fin marked carcasses were observed during the survey (Table 8). CWTs were recovered from two of the these carcasses. Both carcasses with tags were fresh. The other two were decayed making mark identification less certain. Both of the CWTs were from CNFH. One of the CWTs was from a 105 cm FL late-fall-run male (Tag # 054119) from the 1995 brood year; it was recovered on 24 June 1999. The other CWT was from a 66 cm FL winter-run female (Tag # 0501011407) from the 1995 brood year; it was recovered on 12 July 1999.

Radio-tagging Study

The carcass survey crew recovered 2 (15%) of the 13 radio-tagged carcasses. The remaining 11 carcasses were located by the boat crew using a receiver unit. None of these 11 carcasses was considered recoverable, i.e., they were located in deep water or under brush.

No radio-tag signals were detected at the stationary monitoring site. All 13 radio tags released were either located during the roving boat survey or recovered during the carcass survey. All three of the radio-tagged carcasses released above ACID dam were also detected upstream of the dam. All 10 radio carcasses released downstream of the dam were located or recovered between RM 292 and 296.

Two radio-tagged carcasses were recovered by the carcass survey crew, one on July 15 and the second on July 24. The second carcass had also been located by the roving, radio-tag monitoring crew on July 21, and classified as recoverable. None of the other remaining 11 radio-tagged carcasses were considered recoverable; nine were located in deep areas and two were located under overhanging brush.

DISCUSSION

Several more years of survey are planned. These survey's data should then be compared with redd survey data to identify salmon spawning habitat requirements. The low population level may also reduce the efficacy of the population surveys in evaluating habitat needs. If the population is so low relative to habitat availability, little can be determined with these data alone, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat is limiting at these low populations, habitat-flow relationships should be identifiable. Other studies that will augment this component of the overall investigation may include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat.

Population Estimates

Law (1994) found that the Petersen formula consistently showed substantially greater overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, Law found that the Petersen formula overestimated the known population by as much as 151%, and by as much as 84% when only fresh carcasses were used. The population based on the Petersen formula, using fresh carcass data, is 2,262. The estimate calculated from fresh and decayed carcass data is 2,493. There were no recoveries from almost a third of the survey periods when tags were released precluding the use of the Jolly-Seber and Schaefer models.

The most appropriate winter-run escapement estimate to determine population trends is the one derived from the Petersen formula using fresh carcass data. Although this formula will likely overestimate the true population, data will likely be available every year to permit calculation of a population estimate, unlike the Schaefer and Jolly-Seber models. Unless winter-run population increases, there will not be enough tag recoveries to allow use of the Jolly-Seber or Schaefer models in most years even though these models will provide a more accurate estimate.

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999. Includes adults and grilse, fresh and decayed carcasses, but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	3	9	1	2
2	0	0	0	3
3	3	2	1	4
4	1	2	1	0
5	4	1	1	1
6	0	0	0	2
7	1	2	2	3
8	5	1	3	1
9	0	0	3	4
10	4	2	1	5
11	7	9	3	3
12	11	3	4	3
13	8	5	0	1
14	3	5	2	3
15	12	3	5	2
16	8	6	0	0
17	11	8	5	4
18	11	4	3	6
19	8	3	2	6
20	5	4	0	7
21	5	11	3	5
22	4	7	1	8
23	10	7	3	5
24	5	6	1	5
25	4	6	3	7
26	7	3	1	4
27	3	6	2	3
28	1	3	2	1
29	2	6	1	0
30	2	0	1	4
31	1	5	1	0
32	2	1	0	3
33	1	8	0	2
34	0	3	1	0
35	0	3	0	3
36	0	2	1	0
37	1	4	0	0
38	1	2	0	1
Totals	154	152	58	111

Table 8. Summary of adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Date collected	Tag code	Sex	FL (cm)	Race (brood year)
May 14	054119	Male	103	Late fall (1995)
June 13	-	Female	66	-
June 19	-	Female	64	-
July 12	0501011407	Female	66	Winter (1995)

The carcass recovery rate for the 1999 survey was considerable greater than the rates observed during the earlier surveys (15% in 1998, 12% in 1997, and 15% in 1996) (Appendix Table 1). Possible reasons for increased tag recoveries include greater water clarity and more stable flows. During 1999, water clarity exceeded 8 ft during 92% of the survey periods and mean flows fluctuated from only 9,300 to 13,700 cfs. During 1998, water clarity was less than 8 ft during 64% of the surveys while flows fluctuated from 10,000 to 23,500 cfs.

In contrast to winter run, recovery rates observed during the 1995 through 1998 upper Sacramento River fall-run chinook salmon escapement surveys ranged from 26% to 33% (Snider et al. 1999b). Flows during the fall-run survey periods are typically are around 5,000 cfs, which are much less than during the winter-run surveys. Flows during the late-fall-run surveys have fluctuated the most ranging from 5,500 to 29,800 in 1999 and 4,200 to 52,800 in 1998. Recovery rates observed during the 1999 and 1998 late-fall-run surveys were 29% and 6%, respectively.

Effective Spawner Population

The effective spawner population is defined as the estimated number of females that spawned, assuming there were enough males to service all the redds. Only adult females are used here to calculate the effective spawner population since there is some disagreement among agencies responsible for winter-run management as to the contribution of female grilse to the spawning population. Since 89.3% of the adult escapement was female, the estimated adult female population was 1,626 (based on the Petersen formula using fresh carcass data). Prespawning mortality was 3% yielding an estimated effective spawner population of 1,577.

The issue of female grilse contributing to the spawning population needs to be further evaluated. Although the estimated proportion of females that were grilse (per the carcass survey) was very low (3.8%), the estimated proportion of female grilse (based upon the RBDD counts, see below) was high (56.5%). The spawning success data collected during the carcass survey showed that one of the four unspawned salmon was grilse-sized; 16.7% of grilse-sized females was unspawned, compared to 2% of adult-sized females. The unspawned grilse was 45 cm FL, the smallest salmon measured.

Sex Composition

The ratio of males:females for adults only in 1999 was 1:8.4 compared to 1:8.9 in 1998, 1:3.2 in 1997 and 1:6.4 in 1996. Including adults and grilse, the observed ratio during the 1999 carcass surveys was 1:3.0 compared to 1:7.5 during 1998, 1:3.2 during 1997, and 1:2.4 during 1996 (Appendix Table 1). The sex ratio varied throughout the survey ranging from 1:2.2 in May (n = 29), 1:4.4 in June (n = 108), 1:2.0 in July (n = 63) and 1:2.3 in August (n = 11).

The following are possible explanations for the observed sex composition:

1. The recovery rate of males is less than for females. In a carcass survey and weir count conducted on Bogus Creek, a tributary to the Klamath River, the recovery rate of adult males was only 11% less the rate for females (Boydstun 1994).

2. If a high portion of the male population leaves the ocean as 2-year olds, the male to female ratio of that age class remaining in the ocean is reduced significantly. Based on the age composition criteria used in the NMFS model, 50% of the returning males would be grilse. Assuming an initial sex ratio of 1:1, this alone would result in a male to female ratio of nearly 1 to 2. As the proportion of males returning as 2 year olds increases (x), the ratio of male to female adults for that age class decreases to 1:(1/1-x) (e.g., if x = 0.5, the ratio is 1:2; if x = 0.7, the ratio is 1:3.3, *etc.*). Furthermore, if the proportion of males that remain in the ocean for more than three years is different from females, than the number of males returning as 3-year olds would be further decreased.

3. Behavioral differences between males and females after spawning may reduce the relative availability of males to a traditional carcass survey. If, for example, males leave the redd and move to deep pools or downstream out of the survey area, and females remain on the redd, the proportion of females available to the survey would be greater.

4. A combination of the above factors would produce an even greater disparity between adult males and females.

It should be noted that the disparity between males and females has not been observed during surveys of late-fall-run and fall-run salmon in the upper Sacramento River. During 1999 and 1998 late-fall-run surveys, the male:female ratios were 1:1.9 and 1:1.1. Late-fall-run surveys have been conducted during high flow conditions similar to those occurring during winter-run surveys. For fall run, male:female ratios have been 1:1.6 during 1998, 1:1.2 during 1997, 1:1.2 during 1996, and 1:1.6 during 1995. *Therefore, the high ratios of females observed during the winter-run carcass surveys should not be entirely attributed to differences in availability between male and female salmon.*

Age Composition

Length frequency distributions help identify possible trends in age distribution when age-size relationships occur and when sufficient sample sizes are available. Preliminary data obtained from scale analyses conducted by DFG and NCVFWSO indicate that there is significant overlap in size at age.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Based on the salmon counts at RBDD, an estimated 3,208 winter-run salmon migrated upstream. Applying the 61 cm FL criterion[1] to separate adult from grilse, 459 (14.3%) were male adults, 427 (13.3%) were female adults, 1,767 (55.1%) were male grilse, and 555 (17.3%) were female grilse. In comparison, the carcass survey escapement estimate was 2,262 comprising 194 (8.6%) adult males[2], 1,626 (71.9%) adult females, 377 (16.7%) male grilse, and 65 (2.8%) female grilse (Tables 9 and 10, Figure 8).

The population structure defined by the results of the two surveys were quite different. The RBDD data shows a higher proportion of males (2.8 times greater), a higher proportion of grilse-sized fish (6.0 times greater for females and 3.3 times greater for males), and much smaller fish than the carcass survey data. At RBDD, females comprised 30.6% of the sample and had a mean size of 60.7 cm FL (range: 77–82 cm FL). Females comprised 74.8% of the carcass survey and had a mean size of 64.6 cm FL (range: 45–91 cm FL). Males collected at RBDD had a mean size of 55.9 (range: 38–79 cm FL); males collected during the carcass survey had a mean size of 64.6 (range: 46–105 cm FL). The size structure observed at RBDD was comparable to the size distributions observed late in the carcass survey (August) when the size range was compressed and the occurrence of grilse was highest.

Applying the carcass age-size criteria to the RBDD and the RBDD criterion to the carcass survey results yielded little change in the estimated age compositions. Applying the 61-cm criterion to the carcass data yielded a change in the estimated age composition from 8.6 to 9.5% for male adults, 71.9 to 65.7% for female adults, 16.6 to 15.7% for male grilse and 2.9 to 7.1% for female grilse. The overall change in grilse composition for the carcass survey data was 3% (20% using length frequency data criteria, 23% using the 61 cm FL criterion).

Similarly, applying the carcass based criteria to the RBDD data yielded no change in the percent composition of female adults and grilse and an 8% decrease in male adult composition. The percentage of grilse was 19.4% using the carcass survey criteria versus 27.6% using the RBDD criterion. *The disparity in adult:jack ratios between the RBDD and carcass survey results relates more to the differences in size composition than to the different size criteria.*

---

[1] All chinook salmon measured at RBDD that are $\geq$61 cm Fl are considered adults.

[2] The age-size criteria applied to the carcass survey data was adults are >59 cm FL for females and >63 cm Fl for males.

RECOMMENDATIONS

1. Continue the mark and recapture carcass surveys for at least two more years.

2. Investigate the differences between the sex ratios and age composition of fish observed during the carcass survey and fish trapped at RBDD.

3. Expand the radio-tagging survey to evaluate the effects of flow, visibility, and other factors on recovery rates

4. Expand the survey to include investigation of deep pools. The results of the radio-tagging survey show that a large portion of carcasses drift into pools. Separate surveys of the pools could be conducted biweekly to determine the sex, size, and age composition, number of marked and unmarked carcasses that end up in pools, unavailable to the typical carcass survey methods. These data could be compared with the carcass survey results and the radio-tagging survey results to see if there are biases associated with carcasses moving into pools.

5. Age composition and the length at age criteria used to identify the age of female and male winter run should be verified using scales and otoliths collected from the sampled carcasses. Information from known-age CWT winter run should be included in such an evaluation.

6. Evaluate the relationship between age and size of females and contribution to the spawning population.

Table 9. Comparison of results of the RBDD carcass data collected during the winter-run carcass survey, May–August 1999.

	RBDD	Carcass
Total estimate	3,208	2,262
%adult	27.6	80.5
% male adult	13.1	8.6
% female adult	13.1	71.9
Size criteria (grilse/adult)	61	59 female/ 63 male
% male grilse	56.6	16.7
% female grilse	17.1	2.8
No. adult female	427	1,626
No. grilse female	555	65
Total female	982	1,691

Table 10. Comparison of size statistics for male and female winter-run chinook salmon collected at RBDD and during the winter-run carcass survey, May–August 1999.

	RBDD Counts	Carcass Survey
	Male	
Number	68	53
Mean FL	55.9	64.5
Range FL	38-79	46-105
SD	7.62	15.0
	Female	
Number	30	157
Mean FL	60.7	68.1
Range FL	44-82	45-91
SD	9.06	6.6

ACKNOWLEDGMENTS

Survey data were gathered by: Mike Connel, Vina Free, Jeff Green, Jeffery Jahn, Dee McClanahan, Krishnan Nelson, Miguel Olivera, and Randy Rickert with the FWS; Chris Cox, Corrie Carter, Colleen Christensen, Paul Divine John Galos, Brian Humphrey, Carrie Savage, Mike Spiker, Jada-Simone White with the DFG. We thank Jim Smith (FWS) for facilitating a cooperative investigation and Colleen Harvey-Arrison for providing the RBDD information.

LITERATURE CITED

Boydstun, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. Calif. Fish & Game 80(1):1-13.

Croci, S. J. and S. Hamelberg. 1997. Evaluation of the Sacramento River winter chinook salmon (*Oncorhynchus tshawytscha*) propagation program in 1996.   USFWS Report. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, Red Bluff, CA.

Fisher, F. W. 1993. Historical review of winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River, California. CA Dept. Fish & Game Inland Fish Div. Office rept.

Hallock, R .J. and F. W. Fisher. 1985. Status of winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River. CA Dept. Fish & Game Anad. Fish Br. Office rept.

Law, P. M. W. 1994. A simulation study of salmon carcass survey by capture-recapture method.
Calif. Fish & Game 80(1):14-28.

NMFS (National Marine Fisheries Service). 1996. Recommendations for the recovery of the Sacramento River winter-run chinook salmon. Nat. Marine Fish. Serv. Southwest Region, Long Beach, CA. 228 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dept. of Environ., Fish. and Mar. Serv. Bull. 191. 382 p.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. USF&WS Bull. 52:189-203.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Slater, D. W. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements for spawning. U.S. Fish & Wildlife Serv. Spec. Sci. Rept. - Fisheries No. 461 9 pp.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey, lower American River, 1991 - 1992, Final report. Calif. Dept. Fish & Game, Stream Evaluation Program, Envir. Serv. Div.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B. and K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall 1993. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, S. Hamelberg, S. Croci, S. Hill, and E. Kohler. 1997. 1996 Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, and S. Hill. 1998. 1997. Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, and S. Hill. 1999a. 1998. Upper Sacramento River winter-run chinook salmon escapement survey, May–August 1998. Calif. Dept. Fish & Game, Stream Evaluation Program, Habitat Conservation Division.

Snider, B., B. Reavis, and S. Hill. 1999b. 1998. Upper Sacramento River fall-run chinook salmon escapement survey, September–December 1998. Calif. Dept. Fish & Game, Stream Evaluation Program, Habitat Conservation Division.

Taylor, S. N. (Editor). 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 74-12. 32 p.

USF&WS, 1996. Escapement of hatchery-origin winter chinook salmon (*Oncorhynchus tshawytscha*) to the Sacramento River, California in 1995, with notes on spring chinook salmon in Battle Creek. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Service Office, Red Bluff, CA.

APPENDIX

Appendix Table 1. Summary of results from the 1996, 1997, 1998 and 1999 upper Sacramento River winter run spawner surveys.

Parameter	1996	1997	1998	1999
Survey dates	29 April– 5 September	30 April– 29 August	5 May– 28 August	5 May– 27 August
No. of total carcasses	118	239	785	475
No. of fresh carcasses	52	105	382	212
No. of decayed carcasses	66	134	403	263
Tag recovery rate	15%	12%	15%	22%
Estimated population (Petersen)	820	2,053	5,501	2,262
Adult estimate	664	1,888	5,391	1,821
Grilse estimate	156	165	110	441
Adult female estimate	571	1,437	4,847	1,626
Adult male estimate	93	451	544	194
Grilse female estimate	10	92	0	65
Grilse male estimate	146	73	110	377
Female:male ratio: adults/all	6.1:1/2.5:1	3.2:1/3.2:1	8.9:1/7.5:1	8.4:1/3:1
Size criterion (male)	Adult >65 cm	Adult >63 cm	Adult >60 cm	Adult >63 cm
Size criterion (female)	Adult >64 cm	Adult >63 cm	Adult >54 cm	Adult >59 cm
Spawning success (%)	94%	96%	95%	97%
Spatial distribution (Reach 1,2,3, and 4)[1]	50%, 39%, 9%, 2%	48%, 52%	58%, 42%,	73%, 27%,
Peak spawning period	early– mid July	late June - early July	early July	early– mid June
Flow range	7,200–16,200	8,000–15,000	10,000– 23,5000 cfs	9,300– 13,700 cfs
Temperature range	52–59 °F	49–52 °F	50–54 °F	50–54 °F
Visibility range	na	3–10 ft	4.5–11 ft	6–11 ft

FIGURES

Figure 1. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after Week 20 (1969 through 1985).

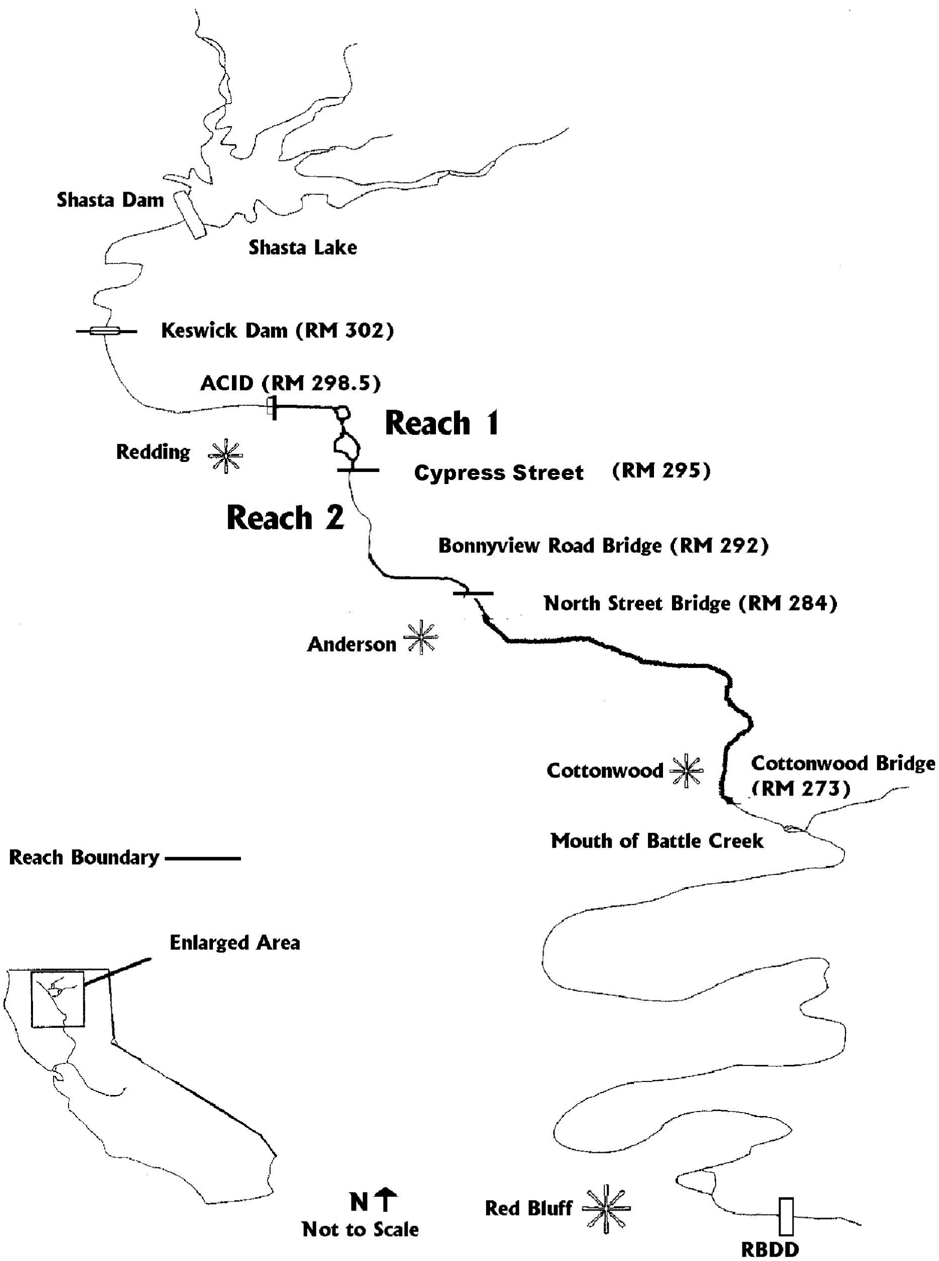


Figure 2. Location of reaches surveyed during the 1999 winter-run chinook salmon escapement survey, May-August 1999.

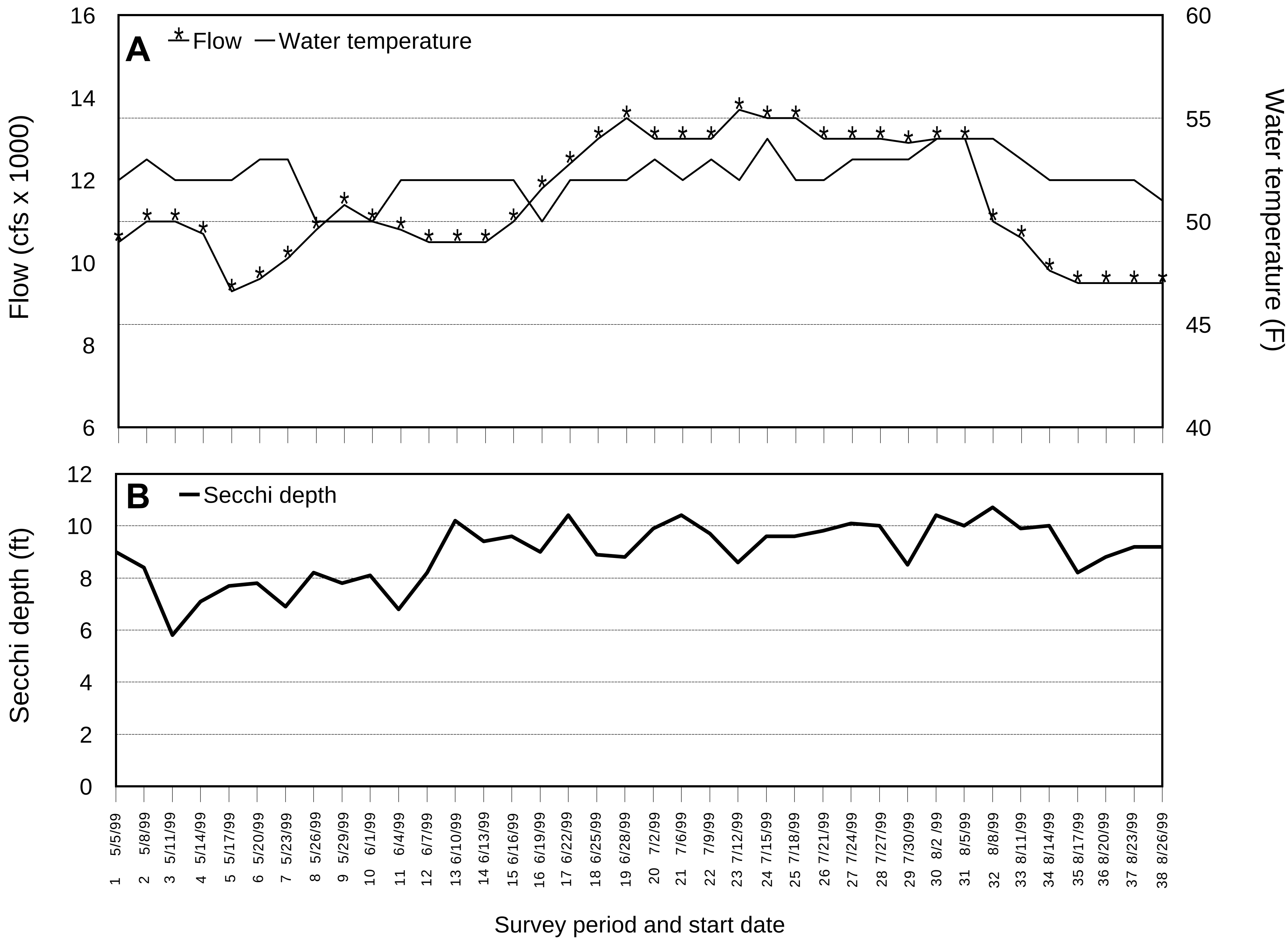


Figure 3. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

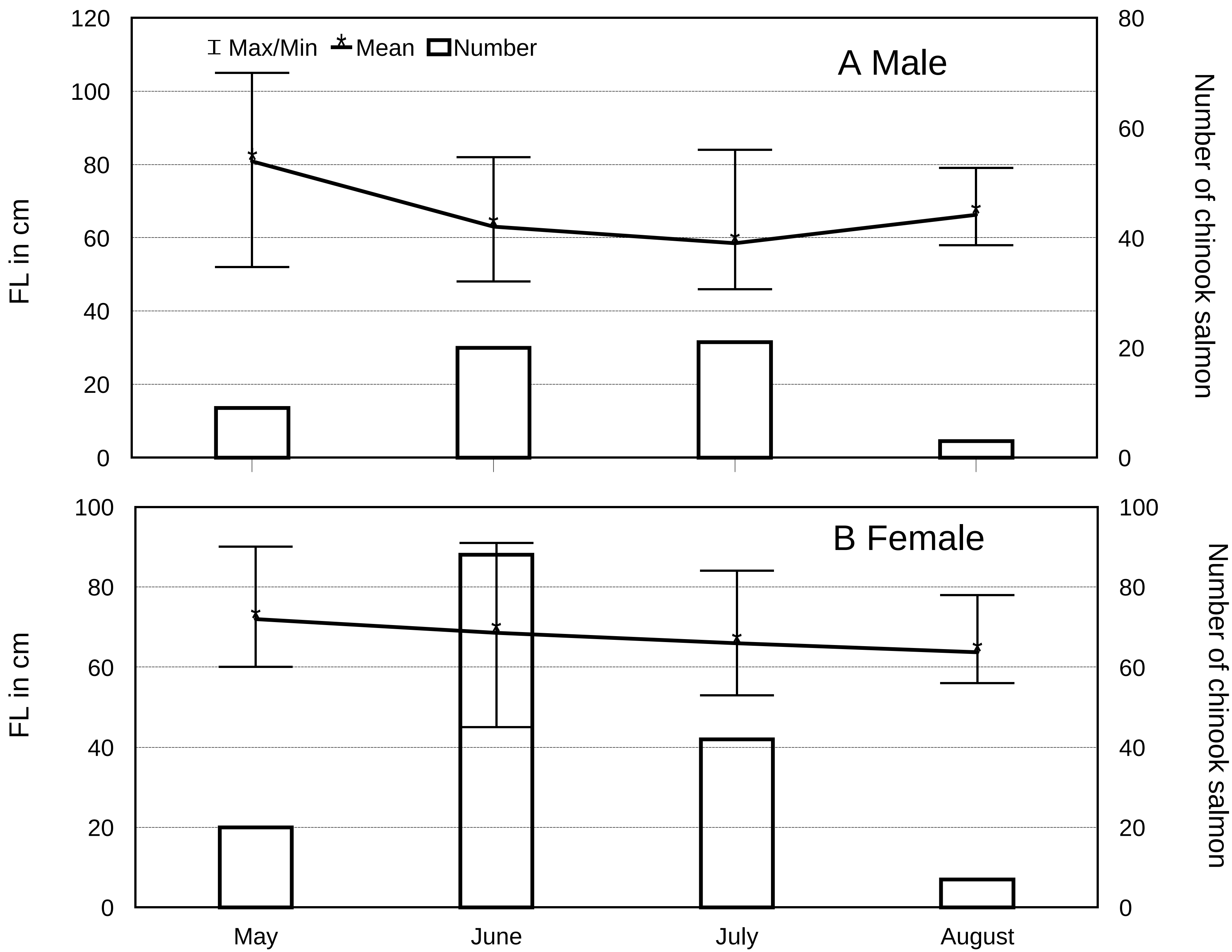


Figure 4. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

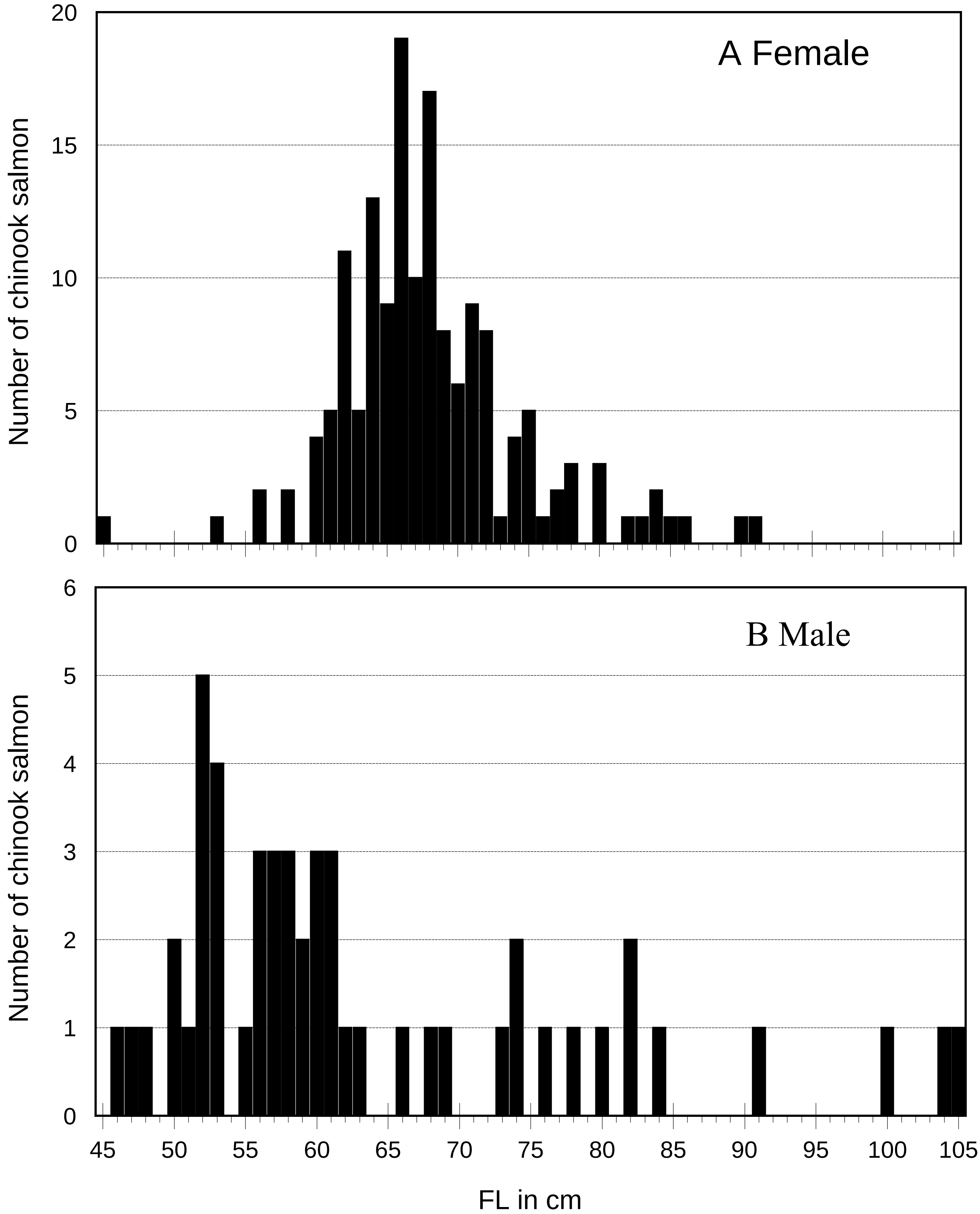


Figure 5. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

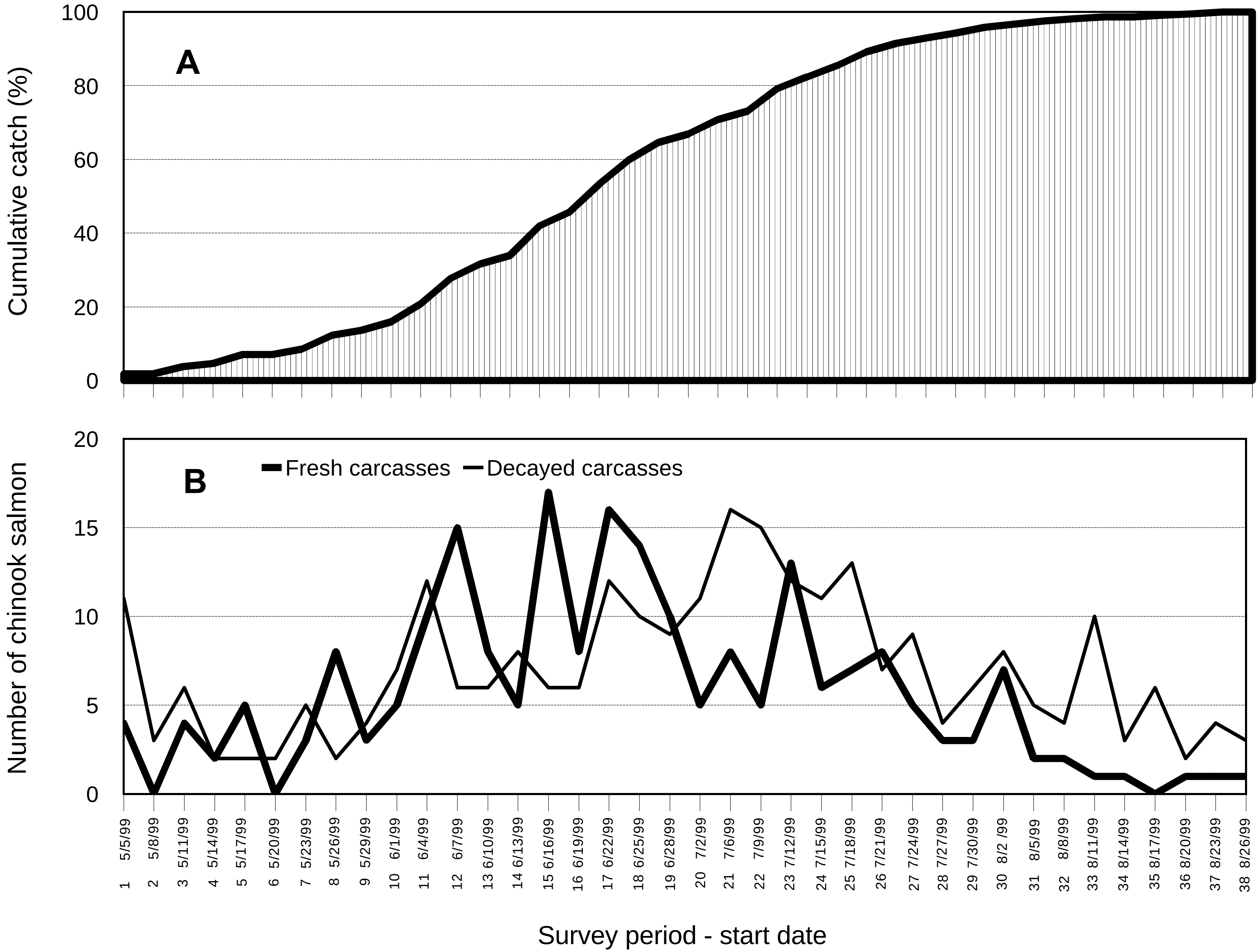


Figure 6. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B), by survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May-August 1999.

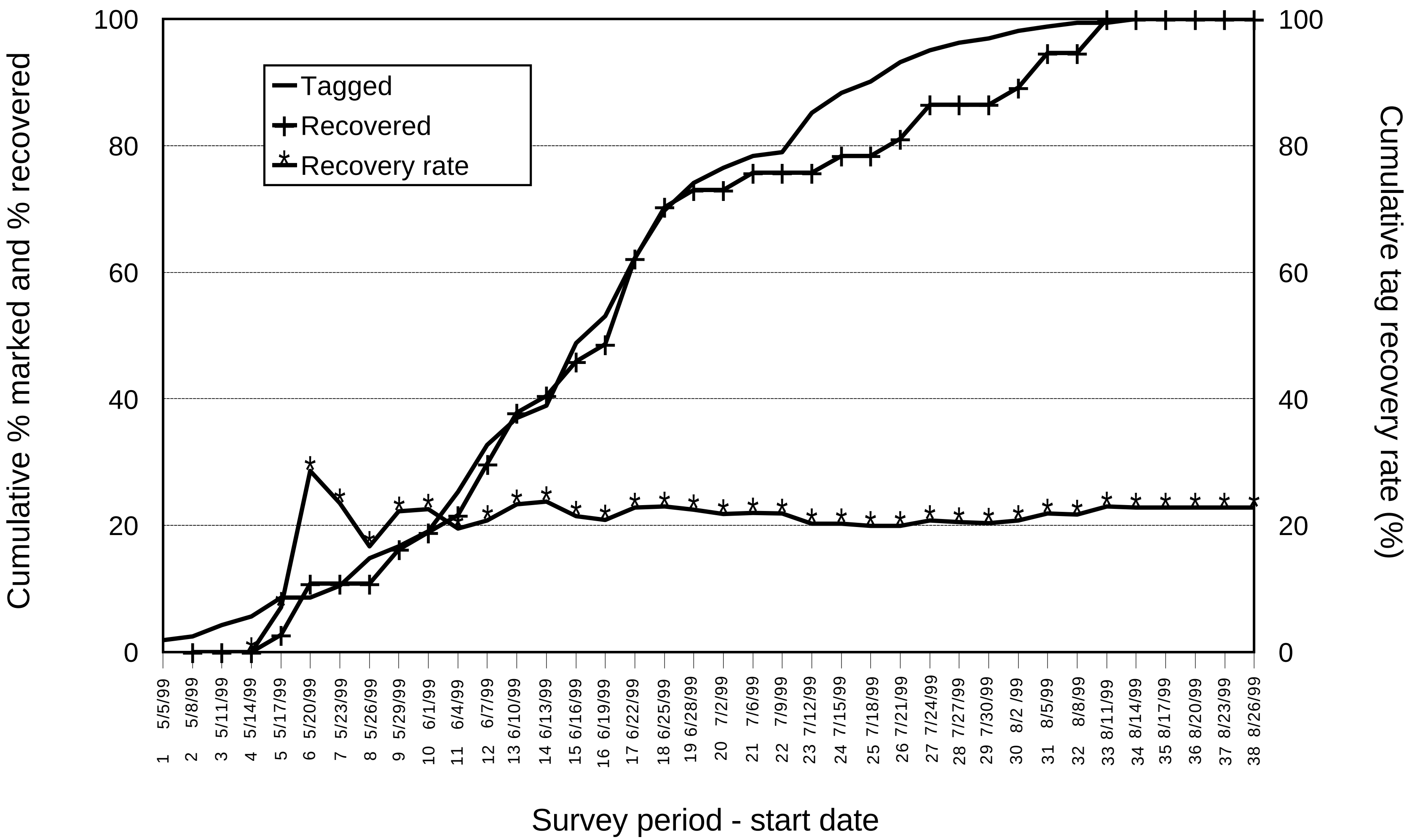


Figure 7. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

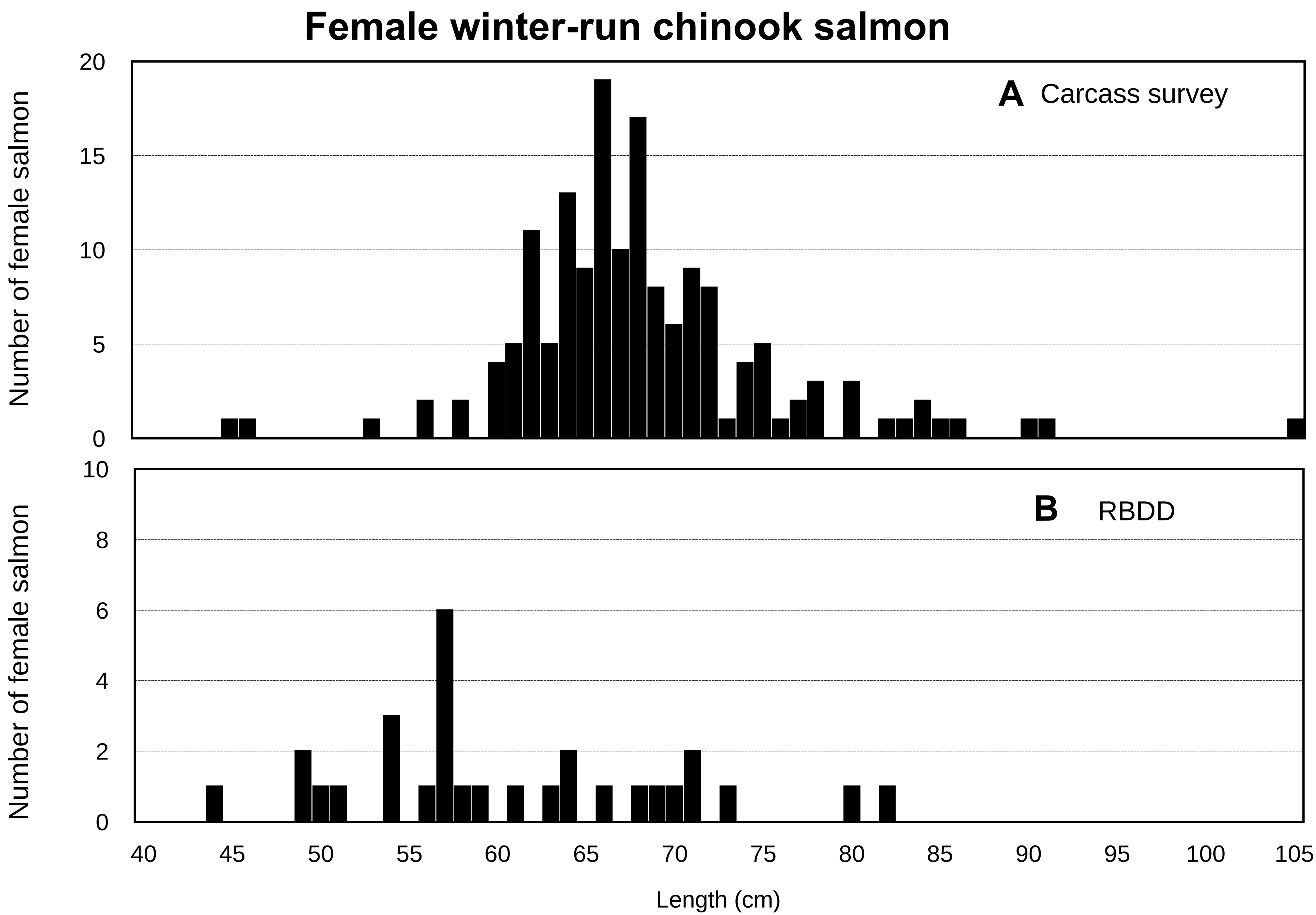


Figure 8. Comparison of length frequency distributions for female winter-run chinook salmon collected during (A) the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 1999.

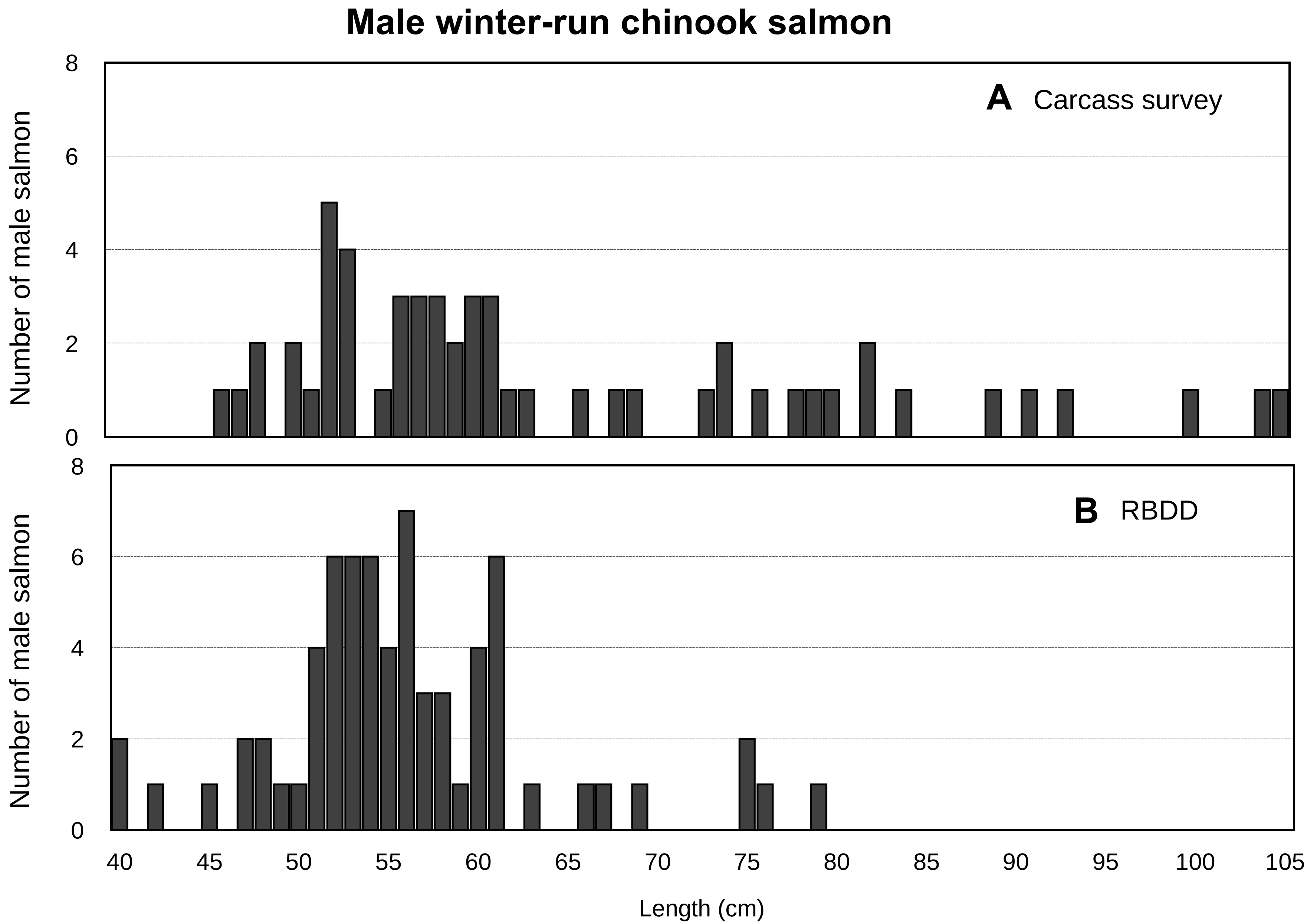


Figure 9. Comparison of length frequency distributions for male winter-run chinook salmon collected (A) during the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 1999.

APPENDIX VI

Cosumnes River survey report

CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

Cosumnes River Chinook Salmon Spawner Escapement, Rearing and Emigration Surveys 1998-99 1/2/

by

Bill Snider
and
Bob Reavis

August 2000

1/ This work was supported by funds provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program, as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report No. 00-7.

TABLE OF CONTENTS

SUMMARY

The Cosumnes River chinook salmon *Oncorhynchus tshawytscha* resource was surveyed from November 1998 through June 1999. Data were acquired on temporal and spatial distribution of salmon spawning and on juvenile rearing and emigration. Physical data were also collected to characterize spawning and rearing habitat conditions. The primary purpose of these surveys was to identify the relationships between the various salmon life stages and existing habitat conditions and eventually identify potential management actions that could help restore the Cosumnes River salmon population to near historic levels.

Fall-run chinook salmon escapement was surveyed from 12 November 1998 through 23 December 1998. Flow during the spawning period was relatively low (100–200 cubic feet per second [cfs]). Temperature was less than 60ºF beginning in early October, and ranged from 50ºF to 36ºF during the survey period. A total of 105 carcasses was observed. Spawner escapement within the survey reach (Meiss Road to Michigan Bar) was estimated using the Petersen mark-and-recapture model to be about 544 salmon (528 adult and 16 grilse). Aerial redd surveys conducted early in the survey period (18 November 1998) indicated that about 95% of spawning occurred within the survey reach. The total estimated escapement for the entire river was 572 salmon. However, based upon a low recovery rate of marked salmon carcasses (18%) and Law's (1994) analysis of carcass mark-and-recapture methods, we concluded that a more reasonable estimate of spawner escapement was between 250 and 350 salmon. Spawning appeared to begin in early November 1998, based upon observance of few decayed or fresh carcasses during the 12 November survey. Spawning peaked during mid-November 1998 and was completed by mid-December 1998.

Seining surveys were conducted to acquire data on temporal and spatial rearing distributions. Juvenile salmon were found rearing from Rancho Murieta upstream to Michigan Bar during March–May 1999. Recently emerged-sized salmon (<45 mm FL) were collected during March–April 1999. The largest salmon collected during March was 53 mm FL, the largest salmon collected during April was 69 mm FL, and the largest salmon collected during May was 77 mm FL. No salmon were collected during June.

Emigration was monitored using a 5-ft diameter rotary screw trap located downstream of the spawning reach (near RM 23). Trapping began late in the season, 7 April 1999. The highest catch rate occurred during the first week of trapping. No emigrating salmon were collected after the first week of June 1999. Recently emerged-sized salmon were captured through mid-May; large, smolt-sized fish (>70 mm FL) were collected every week from 26 April–4 June 1999.

Spawning migration appeared to be delayed by low fall flows. Although temperatures were well below 60ºF during mid October, flow was low, less than 100 cfs at Michigan Bar. Spawning did not appear to begin until flow exceeded 200 cfs at Michigan Bar. Rearing and emigration appeared directly related to temperature rather than flow. Flow was relatively high (>200 cfs) during early June when temperatures exceeded 65ºF and salmon catches declined to zero in both the seining and trapping surveys.

INTRODUCTION

The Cosumnes River chinook salmon *Oncorhynchus tshawytscha* resource was surveyed from November 1998 through June 1999. Data were acquired on temporal and spatial distribution of salmon spawning and on juvenile rearing and emigration. Physical data were also collected to characterize spawning and rearing habitat conditions. The primary purpose of these surveys was to identify the relationships between the various salmon life stages and existing habitat conditions and eventually identify potential management actions that could help restore the Cosumnes River salmon population to near historic levels.

The Cosumnes River has historically supported a moderately sized fall-run chinook salmon population (Taylor 1974, Reavis 1981, Kano 1998). Between 1953 and 1973, the estimated spawner escapement to the Cosumnes River exceeded 1,000 salmon on several occasions, and exceeded 4,000 salmon twice. Since the mid-1970's, however, estimated escapement reached 1,000 fish only once and was generally 200 fish or less. In recent years, chinook salmon reared at Nimbus Hatchery on the American River have been planted into the Cosumnes River. Over 225,000 chinook salmon fry were planted into the Cosumnes River during 1996. These fish could have contributed to the 1998 fall spawner population.

The decline in the salmon population has apparently been due to substantial flow reductions during critical salmon migration periods and a shortage of suitable spawning and rearing habitat. Even though the Cosumnes River is the only river system in the Central Valley that has not been substantially altered by large-scale water development, several small dams[1] and numerous riparian diversions routinely reduce or eliminate surface flows in the lower river from spring through early winter. Low flow during this period has severely restricted and even eliminated chinook salmon immigration and emigration. Similarly, an abundance of fine sediment has apparently increased within the historic anadromous reach, reducing spawning and rearing habitat availability and possibly affecting the timing and abundance of surface flow. The 1998–1999 surveys were intended to establish a basis for addressing these issues.

METHODS

The Cosumnes River enters the Mokelumne River just upstream from the central Sacramento-San Joaquin Delta. The Cosumnes River is typically a rain-fed stream versus snow fed, originating at relatively low elevations on the western slope of the Sierra Nevada. Most of the river is unavailable to anadromous fish (Figure 1). A series of steep cascades located at Latrobe Falls, near river mile (RM) 40, is a total barrier to anadromous fish migration. The reach generally used

---

[1] Jenkinson Reservoir impounded by Sly Park Dam on Sly Park Creek in the upper portion of the Cosumnes River watershed is the only notable water storage facility in the basin. Its watershed comprises less than 4% of the total Cosumnes River drainage.

for salmon spawning and rearing is located between Meiss Road (RM 26) and Latrobe Falls. Generally, this reach constituted the survey area for 1998-1999.

Temperature data were collected using an electronic, recording thermograph located near Michigan Bar Road (RM 36). Flow data were obtained from records for a gaging station located at Michigan Bar that is operated by the U.S. Geological Survey and the California Department of Water Resources.

Chinook Salmon Spawning Survey

A fall-run chinook salmon spawner escapement survey was conducted on the Cosumnes River between Michigan Bar and Meiss Road Bridge[2] (Figure 1). Surveys were conducted every other week beginning on 12 November 1998 and ending 23 December 1998. The objectives of our survey were to determine: i) the number of salmon spawners; ii) spatial and temporal spawning distribution; and iii) length frequency, sex composition, and spawning success (egg retention). Aerial photos were also taken on 18 November 1998 to identify spawning distribution. The numbers of redds and live fish observed during each survey trip were also recorded and, in combination with the aerial photos, will be used to map redds, and, thus, the distribution of spawning habitat used.

A carcass mark-and-recapture survey was used to estimate spawner abundance. The stream reach between the Michigan Bar Bridge and Meiss Road Bridge was divided into two sections: 1) Michigan Bar to Highway 16 Bridge, and 2) Highway 16 Bridge to Meiss Road Bridge. The upstream section was surveyed on foot by Department of Fish and Game (DFG) personnel; the downstream section was surveyed from a canoe by Fishery Foundation staff.

Carcasses were collected and checked for completeness (i.e., with the head intact) and previously attached tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included those: i) previously tagged, ii) on shore in a "leathery condition"; and, iii) in the downstream portion of Section 2 that would likely wash out of the survey area and never be recovered. Tagged carcasses were released into running water for recapture.

Data collected to estimate population size included the number of tagged, chopped, and recovered carcasses. All carcasses were examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from primarily fresh carcasses included gender, fork length (FL) in centimeters, section of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, as partially spent if a substantial amount of the eggs remained, and

[2] This reach was annually surveyed by the DFG from 1953 until 1989.

unspent if the ovaries appeared nearly full of eggs. Carcasses were also examined for adipose-fin clips indicating presence of a coded-wire tag.

During data analysis, salmon $\geq$72 cm FL were classified as adults (>2 years old), while those <72 cm FL were classified as grilse (2 year olds). The break at 72 cm FL was based upon size distribution of carcasses measured during this survey (Figure 3).

Escapement was estimated using the Petersen formula (3.7) as described by Ricker (1975):

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where, N = estimated spawning population,
M = number of carcasses marked during the survey,
C = total number of carcasses examined during the survey, and
R = number of marked carcasses recovered during the survey.

Salmon Rearing Habitat Surveys

Salmon rearing habitat was surveyed from 23 March 1999 to 14 June 1999. The rearing habitat evaluation was intended to determine the temporal and spatial distributions of the various juvenile life stages occurring in the Cosumnes River. Sampling was conducted at approximately one-month intervals. The sampling sites were located near the mouth of Indian Creek (about 2.5 miles upstream of Michigan Bar), near Michigan Bar bridge, on Rancho Murieta property up and downstream of the Highway 16 Bridge, and at the Meiss Road Bridge.

Sampling was conducted using either a 25 x 4-ft or a 50 x 4-ft beach seine, depending upon sampling conditions. The larger seine was used about 1/3 of the time, typically where the stream was wide and a large seine could be easily maneuvered. Sites sampled with the large seine included those near Michigan Bar and near the Rancho Murieta airport. The smaller seine was typically used where the stream was narrow and the current was swift. Data recorded from each seine haul included the number of salmon caught, size of up to 50 salmon per haul (i.e. fork length [FL] to the nearest 0.5 mm and weight to the nearest 0.2 g) and the general habitat attributes of the site seined (e.g., area, depth, current velocity, water temperature).

Emigration Survey

The purpose of our monitoring was to determine the timing and relative abundance of juvenile fall-run salmon emigration. Timing and abundance will be compared with precedent conditions of spawning and rearing in the upper natal stream to identify relationships between manageable habitat conditions (e.g., flow, habitat availability) and salmon survival to emigration.

Emigrating juvenile salmonids were monitored at the Folsom South Canal crossing (Figure 1) using a 5-ft diameter rotary screw trap (RST). Sampling occurred from 7 April 1999 through 14 June 1999. The trap was generally serviced two to four times per week. Data recorded during each servicing included number of hours fished since the last service and the number and sizes of collected salmon. Fish were removed from the trap, sorted, and counted. All salmon were measured and weighed (FL in mm and weight in g).

RESULTS and DISCUSSION

General Results

Mean weekly flow, measured at Michigan Bar[3], during the 1998–1999 water year ranged from 26 cubic feet per second (cfs) during September 1999 to over 5,500 cfs during week 7 (7–13 February 1999). Flow was relatively low until week 4 of 1999 (17–23 January 1999) when mean weekly flow first exceeded 1,000 cfs (Figure 2). During the spawner immigration period, flow was moderately low. Mean daily flow did not exceed 100 cfs until 8 November 1998 (119 cfs), and did not exceed 200 cfs until 24 November 1998. Flow did not substantially increase until week 49 when mean daily flow exceeded 700 cfs. Mean daily flow during the emigration period remained relatively high into June 1999 (Figure 2) reaching 200 cfs by mid-June then remaining below 100 cfs after 1 July 1999.

Mean daily temperatures measured near Michigan Bar ranged from 36°F during week 52 to over 80°F during September 1999 (Figure 2). Mean weekly temperature declined to 60°F early in October (week 42), although flow was less than 70 cfs at the time.

Chinook Salmon Spawning Survey

Flow during the spawner survey ranged from 105 cfs during the first survey week (week 46) to about 200 cf during the second and third survey (weeks 48 and 50) then declined to 138 cfs during the fourth survey week (week 52) (Table 1). Water temperature declined from around 50 °F to 36 °F during this survey.

---

[3] During the low flow season, flows measured at Michigan Bar are higher than the flows present downstream due to diversions.

Table 1. Summary of flow, water temperature, redd counts, live salmon counts, carcass counts, and tagging results during the fall-run chinook salmon survey of the Cosumnes River, November - December 1998.

Survey period (date)	Section	Flow (cfs)	Temperature °F	Salmon carcasses: Fresh adult/grilse	Salmon carcasses: Decayed	Redds	Live salmon
1 Week 46 (12 Nov)	1	105	50	3	2	26	35+
	2	Not surveyed					
2 Week 48 (24 Nov)	1	202	51	14	1	26	18
	2	202	51	5	12	81	56
3 Week 50 (8–9 Dec)	1	203	42	1	0	44	5
	2	201	43	10	30	132	31
4 Week 52 (23 Dec)	1	Not surveyed					
	2	138	36	4 / 1	22	-	3
All	1			18	3	96	58
	2			20	64	213	90
	Total			38	67	309	148

We observed 105 carcasses including 38 fresh carcasses (37 adults [97%], 1 grilse [3%]), and 67 that were classified as decayed or skeletons (Table 1). Thirty-three carcasses were tagged and six (18%) were later recovered. Total estimated escapement for the survey reach, using the Petersen formula, was 544 salmon (528 adults, 16 grilse). Based on aerial redd photos, over 95% of spawning occurred between Michigan Bar and Meiss Road Bridge; thus, spawner escapement to the Cosumnes River was about 572 salmon.

The spawner escapement estimate of 544 calculated from the Petersen formula is likely an overestimate based on Law's (1994) analysis. Law concluded this formula could more than double the actual population particularly when the recovery rate is low as it was in this study (18%). As such, we concluded that the actual spawner population size was more likely between 250 and 350 adult salmon.

Forty carcasses were measured and sexed. The only carcass classified as a grilse was a male measuring 60 cm FL (Figure 3). Females (n=23) ranged from 72 to 91 cm FL; males (n=17) ranged from 60 to 97 cm FL. All but one male was $\geq$ 73 cm FL. The ratio of females:males was 1.35:1. Twenty-one (91%) of the 23 females examined for egg retention had completely spawned, and two (9%) had only partially spawned.

Spawning was concentrated between the first and third surveys (12 November 1998–9 December 1998) (Figure 4). The highest numbers of redds (176, 57%) and carcasses (41, 39%) were counted during the third survey week (6–12 December 1998) (Table 1). We also counted 107 redds (35%) and 32 carcasses (30%) during the second survey week (22–28 November 1998). Redds constructed subsequent to surveys in previous weeks were not easily distinguished. As such, the number of carcasses counted is likely a more reliable indicator of temporal spawning distribution, although there was no discrepancy in this case.

Results of the aerial photographic surveys and the carcass surveys indicated that most spawning occurred between Meiss Road and Highway 16. Over 69% of the redds counted during the carcass survey and 55% of the redds counted from the aerial photographs were in this section. Sixteen redds (3%) were counted upstream of Michigan Bar on the aerial photographs.

Salmon Rearing Habitat Surveys

Flow during the rearing phase of the survey (March–June 1999) ranged from more than 1,500 cfs during week 17 to less than 100 cfs during week 27 (Figure 2). Mean weekly temperature ranged from 45ºF during week 15 to 78ºF during week 27 (Figure 2).

A total of 498 juvenile salmon was collected in 45 seine hauls made biweekly from 23 March 1999 through 29 June 1999 (Table 2, Figure 5). Twenty-one percent (107) were collected in 13 hauls during March, 66% (327 in 8 hauls) in April, 13% (64 in 11 hauls) in May and zero in 13 hauls during June.

Table 2. Catch statistics for chinook salmon collected by beach seine in the Cosumnes River, March–June 1999.

Date	Location	Area seined (ft^2)	Number caught (n)	n/1,000 ft^2	Mean FL in mm (range)
23 March	Ranch Murieta (RM) airport	429	1023.3	23.3	41.8(38–52)
23 March	Meiss Rd Bridge	83	0	0.0	-
23 March	Michigan Bar	1,397	1	0.7	34.0(34)
23 March	Michigan Bar	322	0	0.0	-
23 March	RM airport	N/A	15	N/A	40.7(39–49)
24 March	RM Golf Course	1,376	0	0.0	-
24 March	RM Golf Course	519	0	0.0	-
24 March	RM Golf Course	558	1	1.8	38(38.0)
24 March	RM Golf Course	N/A	0	N/A	-
24 March	RM Golf Course	N/A	0	N/A	-
24 March	RM airport	992	7	7.1	37.7(35–40)
24 March	RM	360	0	0.0	-
24 March	RM airport	995	73	73.4	43.2(37–53)
	March Totals		107		42.4(34–53)
21 April	Indian Creek	319	7	21.9	45.1(36–58)
21 April	Indian Creek	378	0	0.0	0
22 April	RM Golf Course	155	0	0.0	0
22 April	RM Golf Course	168	101	602.0	47.7(37–68)
22 April	RM airport	928	33	35.6	44.7(40–61)
22 April	RM airport	1,209	40	33.1	49.2(39–64)
23 April	Michigan Bar	1,035	2	1.9	61.5(61–62)
23 April	Michigan Bar	746	144	193.0	44.1(34–60)
	April Totals		327		46.0(34–68)

Table 2 (cont.)

Date	Location	Area seined (ft^2)	Number caught		Mean FL in mm (range)
19 May	RM Golf Course	1,541	19	12.3	61.8(55–71)
19 May	RM airport	992	10	10.0	62.4(55–77)
19 May	RM airport	1,106	5	4.5	57.0(50–62)
19 May	RM airport	1,838	6	3.3	62.8(57–77)
20 May	Michigan Bar	1,406	1	0.7	59.0(59)
20 May	Michigan Bar	294	8	27.2	68.1(61–74)
20 May	Michigan Bar	412	2	4.9	65.5(62–69)
20 May	Michigan Bar	595	0	0.0	-
20 May	Indian Creek	314	2	6.4	61.0(61)
20 May	Indian Creek	412	11	26.7	57.6(48–67)
20 May	Indian Creek	776	0	0.0	-
	May Totals		64		61.7(48–77)
4 June	-	957	0	0.0	-
4 June	-	744	0	0.0	-
8 June	RM airport	760	0	0.0	-
8 June	RM airport	768	0	0.0	-
8 June	RM airport	1,022	0	0.0	-
8 June	RM Golf Course	382	0	0.0	-
8 June	RM Golf Course	481	0	0.0	-
29 June	Indian Creek	450	0	0.0	-
29 June	Indian Creek	164	0	0.0	-
29 June	Indian Creek	145	0	0.0	-
29 June	Michigan Bar	585	0	0.0	-
29 June	Michigan Bar	392	0	0.0	-
29 June	Michigan Bar	470	0	0.0	-
	June Totals		0	0.0	
	Season Totals		498		34–77

Juvenile salmon densities ranged from 0.0 fish/ft^2 to over 600 fish/ft^2 (Table 2). The highest densities were hear Rancho Murieta early (March and April) and in the upper reach later (May).

Salmon sizes ranged from 34–53 mm FL (mean = 42.4 mm FL) in March, from 34–68 mm FL (mean = 46.0 mm FL) in April, and from 48–77 mm FL (mean = 61.7 m FL) in May (Figures 6 and 7). Recently emerged-sized salmon (<45 mm FL) were last captured during the April 23 seining survey.

Emigration Surveys

The mean weekly flow during this survey increased from 1,048 cfs in week 15 (4–10 April 1999) to 1,454 cfs in week 17 (18–24 April 1999), then gradually decreased to a low of 268 cfs during the last week of trapping (13–19 June 1999) (Table 3, Figure 2). Mean weekly water temperatures generally increased during this survey from 45°F during week 15 to 70° F during week 25. Temperature first exceeded 60°F during week 22.

Weekly catch/hr ranged from 0.25fish/h in weeks 15 and 17 down to 0.00 during weeks 24 and 25 (Figure 8). Given that the peak in seine survey catches occurred during April 1999, we concluded that the peak of emigration was also represented in our trapping effort (cf. Figures 5 and 8). The mean weekly size increased as the season progressed from 38.7 mm FL in week 15 to 78.1 mm FL in week 23 (Figure 9). Recently emerged-sized salmon were last caught during week 20 (9–15 May 1999) (Figures 9–12).

Table 3. Summary of rotary screw trap catches for the Cosumnes River during 4 April 1999 through 14 June 1999. The trap was located at the Folsom South Canal crossing.

Week	Dates trap were serviced	Mean weekly flow - (cfs)	Mean weekly temperature °F	Hours fished	Number salmon caught	Mean (range) FL in mm	Catch/hr
15	8, 9 April	1,048	46	44	11	38.7(33–47)	0.25
16	12, 14, 16 April	1,237	54	165	30	38.1(35–47)	0.18
17	19, 21, 23 April	1,454	55	120	30	38.3(33–48)	0.25
18	26, 30 April	1,032	54	168	21	52.8(36–90)	0.125
19	3, 5, 7 May	984	54	166	19	62.4(38–85)	0.11
20	10, 12, 14 May	816	57	168	31	63.8(39–75)	0.18
21	17, 19 & 21 May	649	59	170	14	67.9(56–82)	0.08
22	24, 26 May	716	64	121	11	70.0(62–82)	0.09
23	30 May, 1, 3, 4 June	511	62	166	11	78.1(72–86)	0.06
24	7 June	358	66	73	0	-	0.00
25	14 June	268	70	168	0	-	0.00
Totals				1,530	178	33–90	0.12

CONCLUSIONS

Salmon life history activity in the Cosumnes River appeared strongly linked to flow and temperature during the 1998-1999 surveys (Figures 13 and 14). Temperature declined below 60 ºF early in October, when flow was well below 100 cfs at Michigan Bar. However, spawning did not begin until late November, after flows at Michigan Bar, and possibly downstream, had increased to above 200 cfs. Apparently low flows delayed upstream salmon migration and spawning, relative to our knowledge of chinook salmon spawning elsewhere in the Central Valley.

The spawning period was relatively short occurring while flows were well below the eventual high levels brought on by storms during mid-January. Emergence occurred up to at least 27 weeks after spawning started, 25 weeks after peak spawning, ending in mid-May as flow declined and temperatures approached 60 ºF (Figures 13 and 14). The numbers of salmon caught by RST and seine correspondingly decreased as temperature increased and flow decreased. Salmon catches reached zero in early June when temperatures reached above 65 ºF. Apparently rising temperatures forced juvenile salmon to leave the natal stream reaches.

Estimated escapement was relatively high compared to the post 1970 estimates (Figure 15). As discussed above, escapement estimates made since the mid-1970s were typically less than 200 compared to the 1998–1999 estimate of nearly 600 salmon.

ACKNOWLEDGMENTS

The Cosumnes River surveys were supported by funding from the US Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program pursuant to the Central Valley Project Improvement Act intended to improve anadromous fish habitat in California's Central Valley streams. Trevor Kennedy and Keith Whitener collected carcass survey data under contract with the Fishery Foundation. Survey data were gathered by Anthony Ciarico, Robert Coyan, William Guthrie and Ray Von Flu, all with the DFG. Katherine Berry, Olivia Willis and Katy Janssen with the DFG assisted in preparing the graphics.

LITERATURE CITED

Law, P. M. W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif.Fish & Game. 80(1):14-28.

Kano, R .M. (ed.). 1998. Annual Report. Chinook salmon spawner stocks in California's Central Valley, 1989. Inland Fish. Div. Admin. Rept. 98-2.

Reavis, R. L . Jr. (ed.). 1981. Chinook (King) salmon spawning stocks in California's Central Valley, 1979. Inland Fish. Div. Admin. Rept. 81-4.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dept. of Environ., Fish. and Mar. Serv. Bull. 191. 382 pp.

Taylor, S. N. (ed.). 1974. Chinook (King) salmon spawning stocks in California's Central Valley, 1972. Inland Fish. Div. Admin. Rept. 74-6.

FIGURES

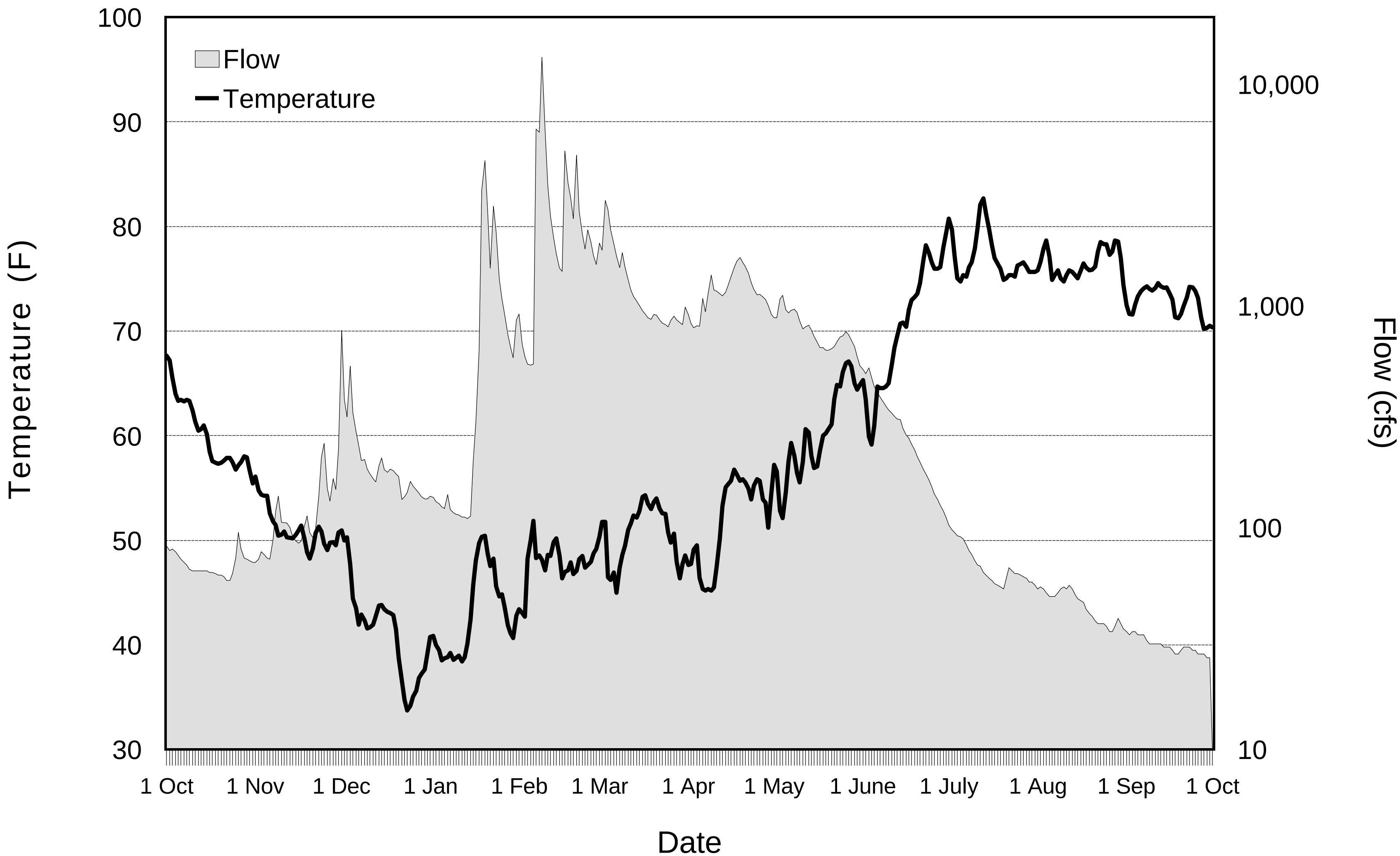


Figure 2. Mean daily flow (cfs) and temperature (F) measured near Michigan Bar (RM 36) on the Cosumnes River, October 1998 - September 1999.

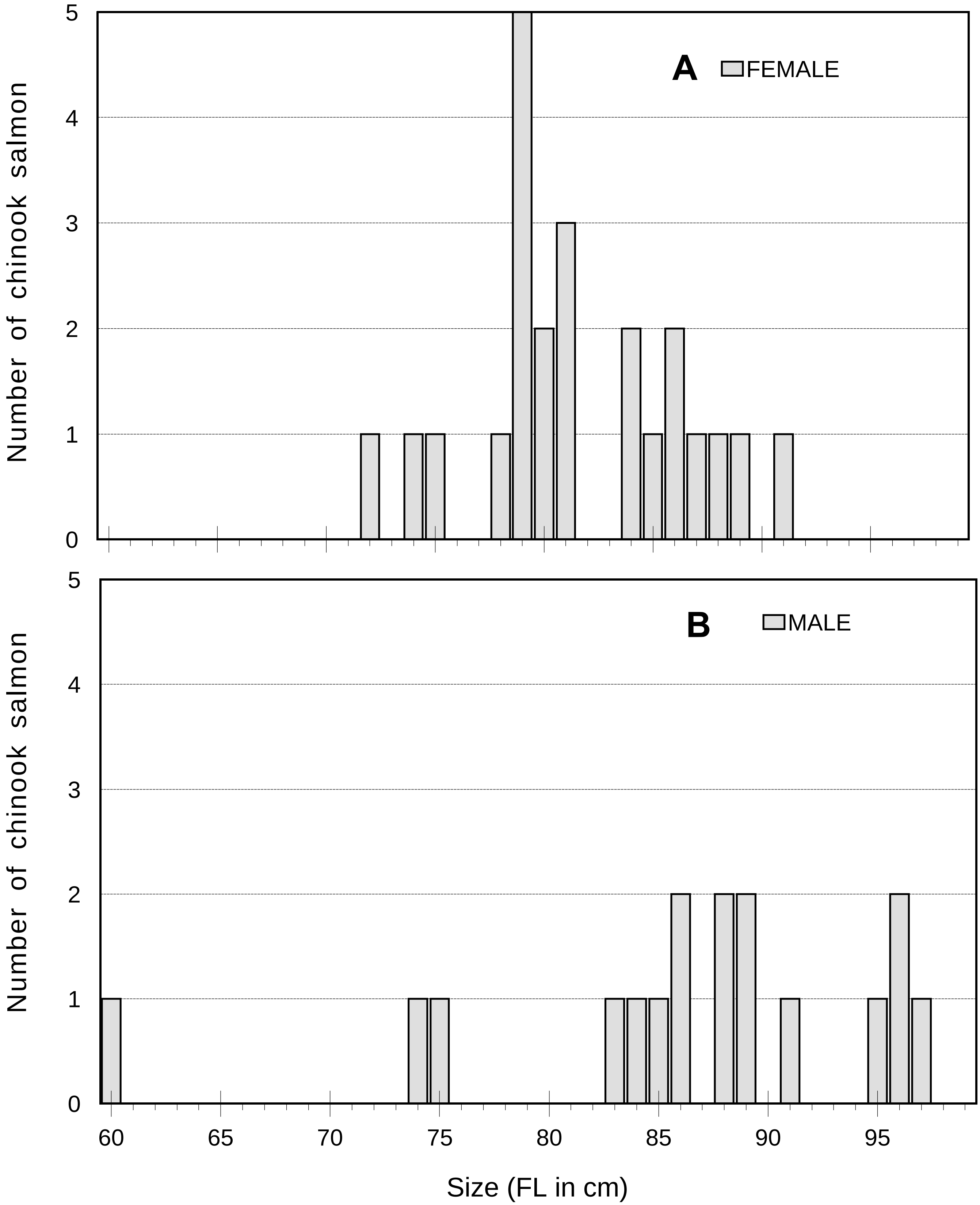


Figure 3. Length-frequency distributions for (A) female and (B) male salmon measured during the Cosumnes River fall-run chinook salmon escapement survey, November - December 1998.

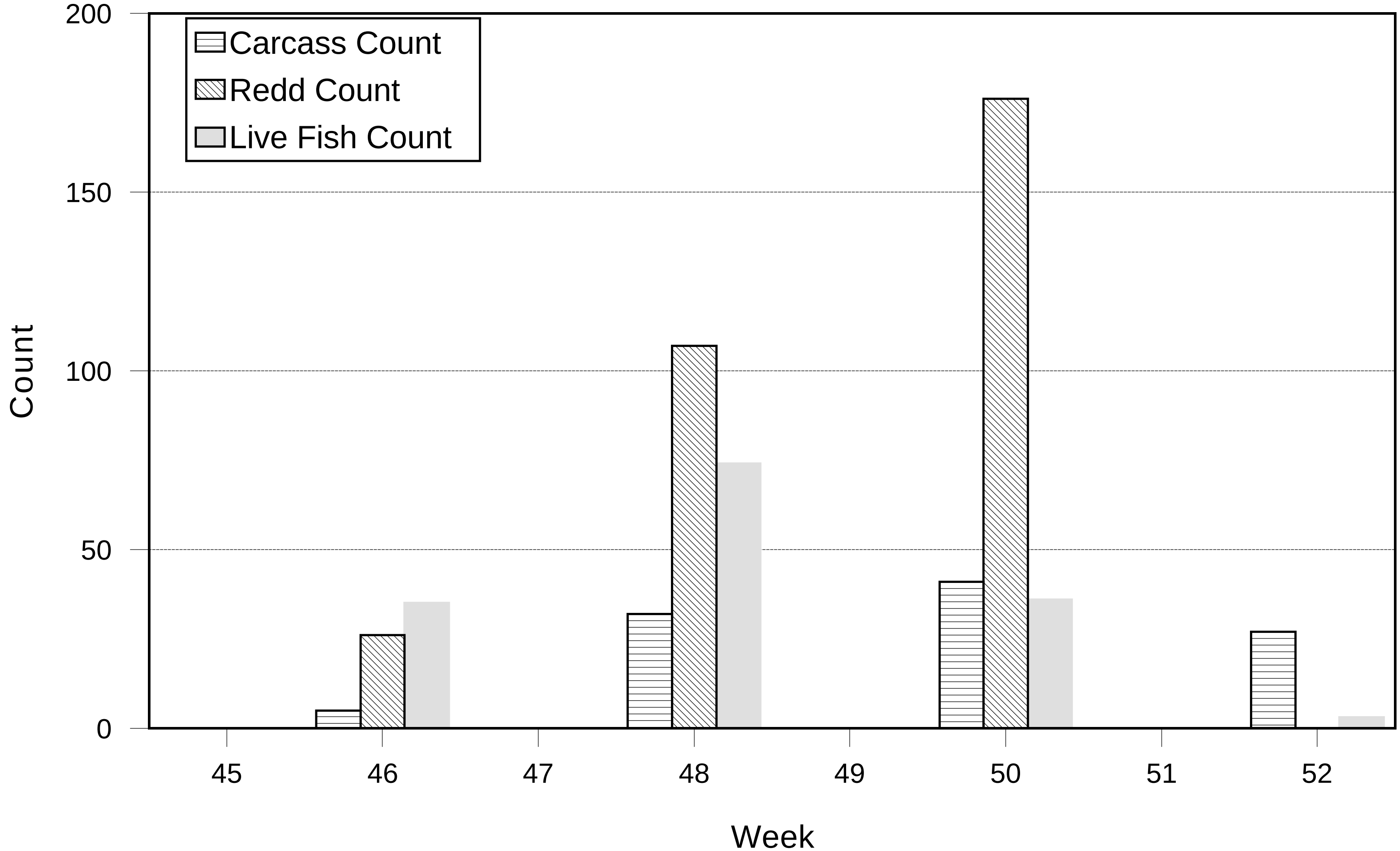


Figure 4. Temporal distribution of carcass counts (fresh and decayed), redd counts and counts of live salmon made on the Cosumnes River, 12 November - 23 December 1998.

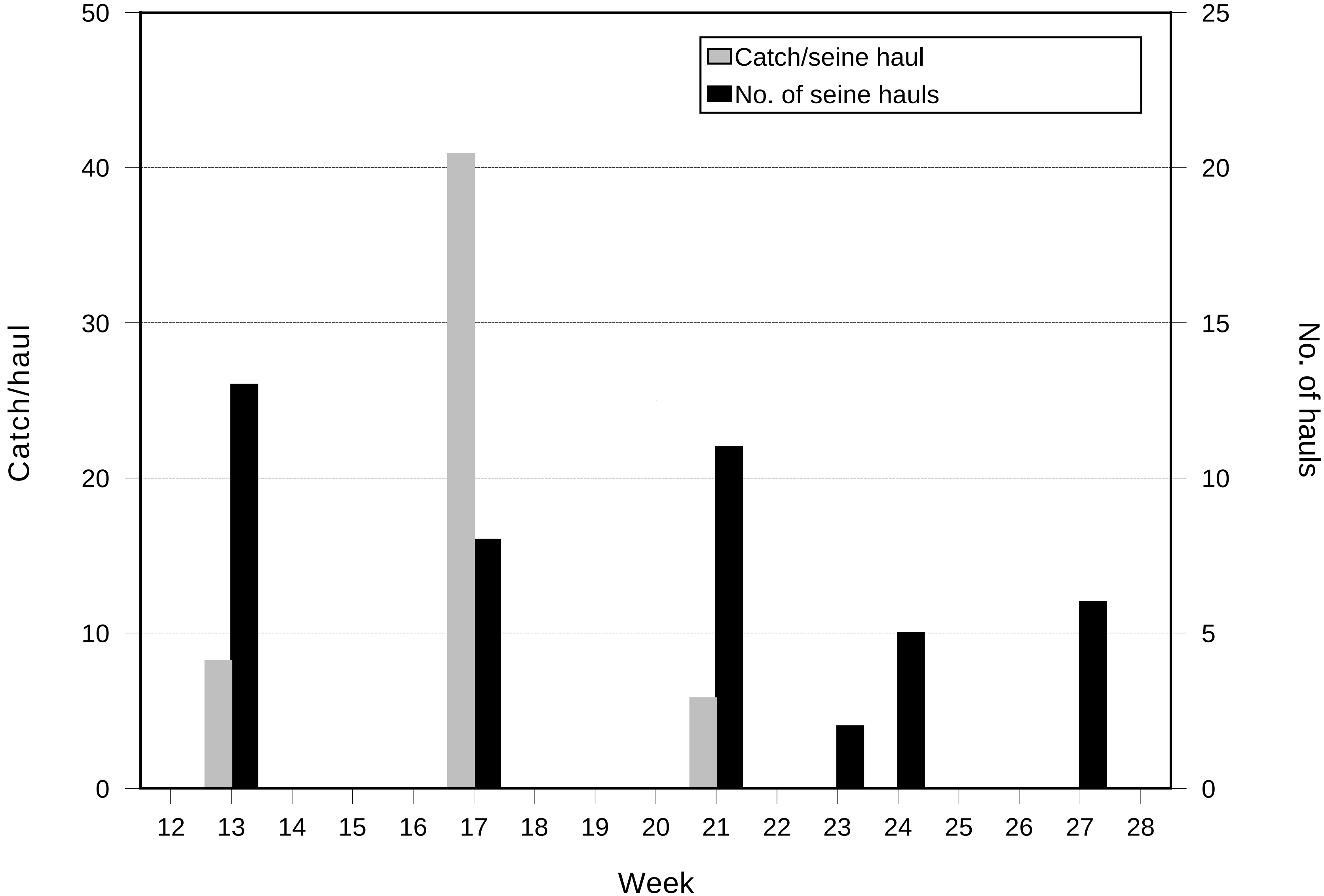


Figure 5. Temporal distribution of seining effort and catch made during the salmon rearing survey on the Cosumnes River, 23 March - 29 June 1999.

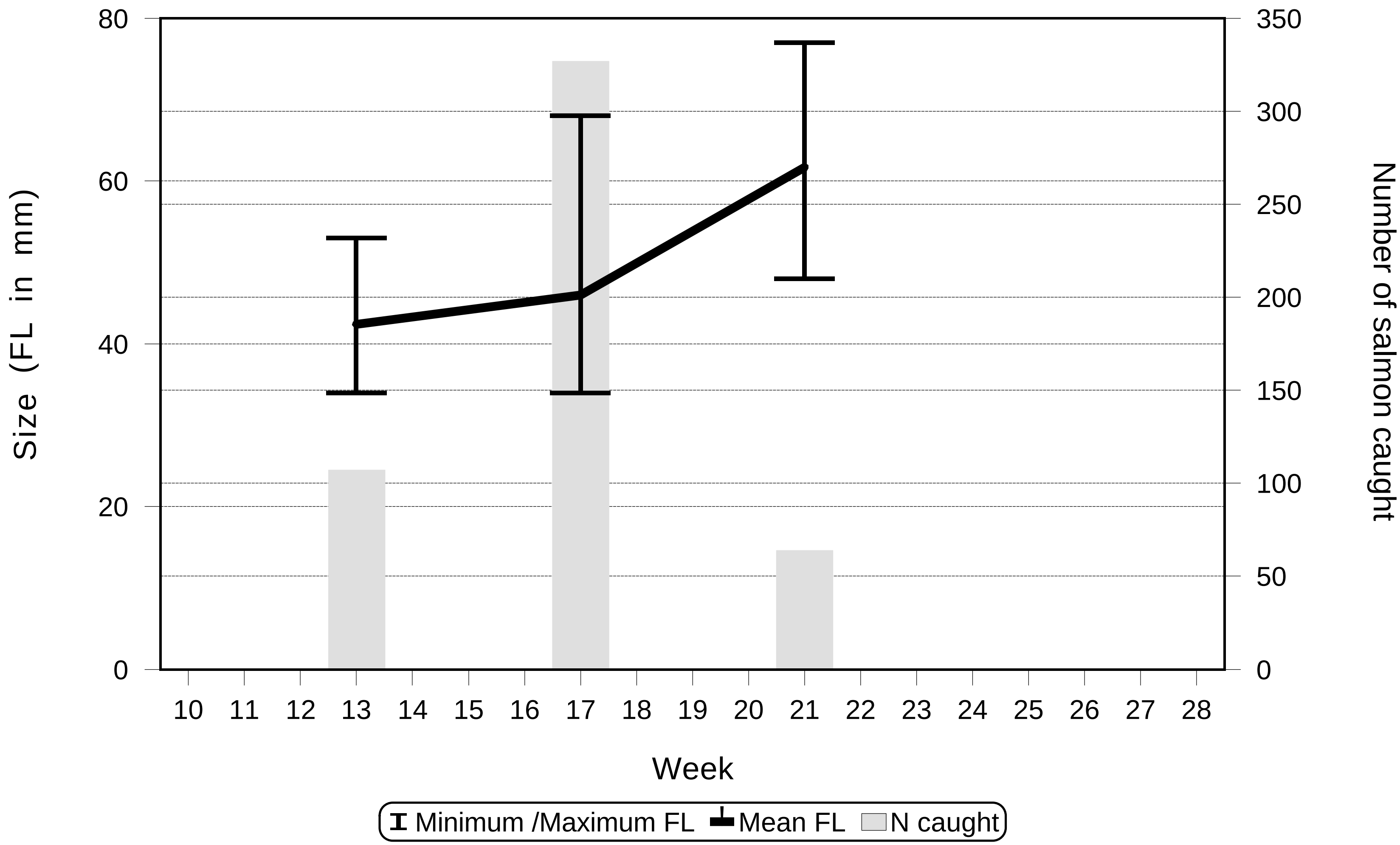


Figure 6. Temporal distribution of size (FL) and number of salmon caught by seine during the salmon rearing survey on the Cosumnes River, 23 March - 29 June 1999.

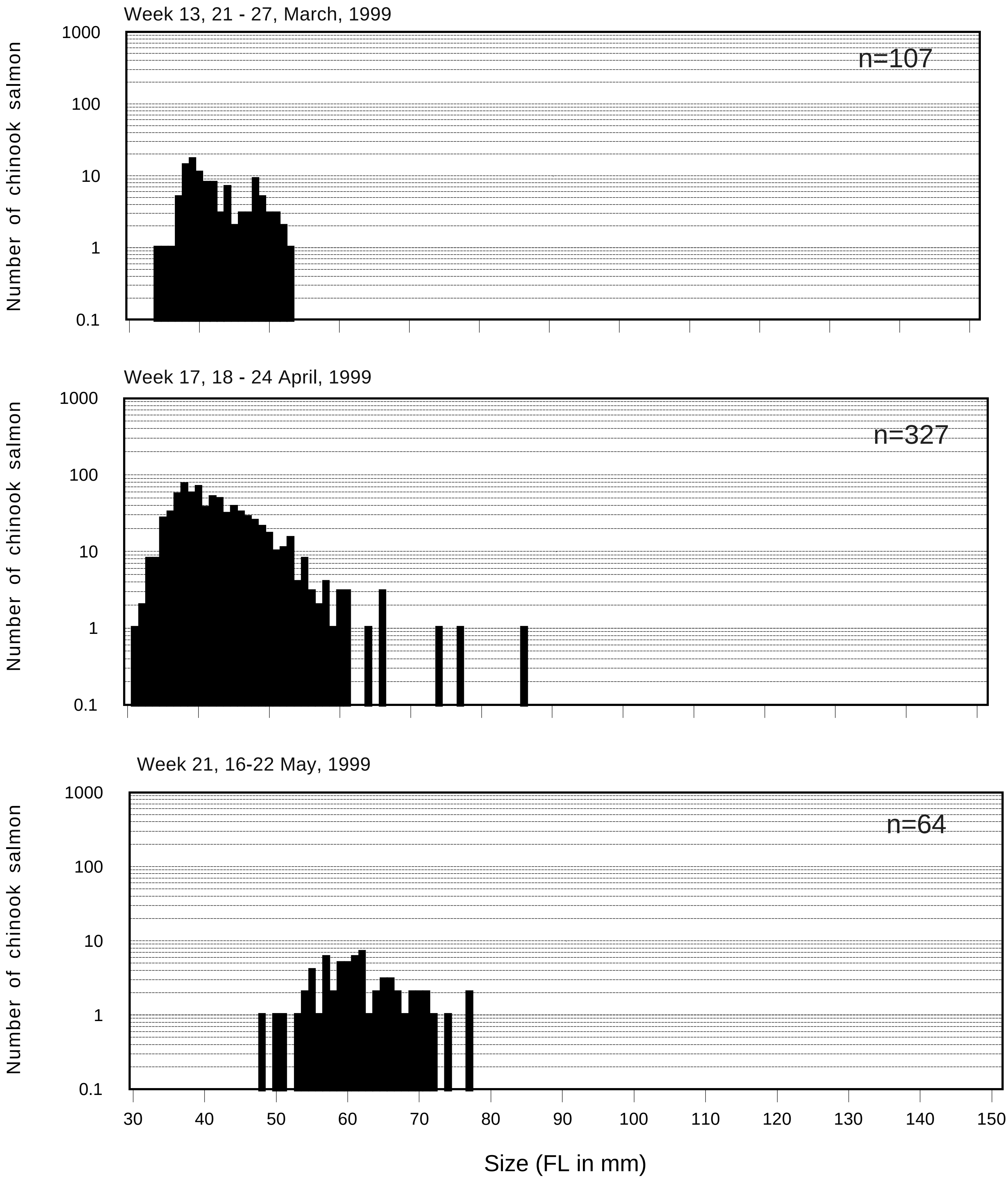


Figure 7. Size distribution of chinook salmon collected by beach seine in the Cosumnes River, 21 March - 22 May 1999.

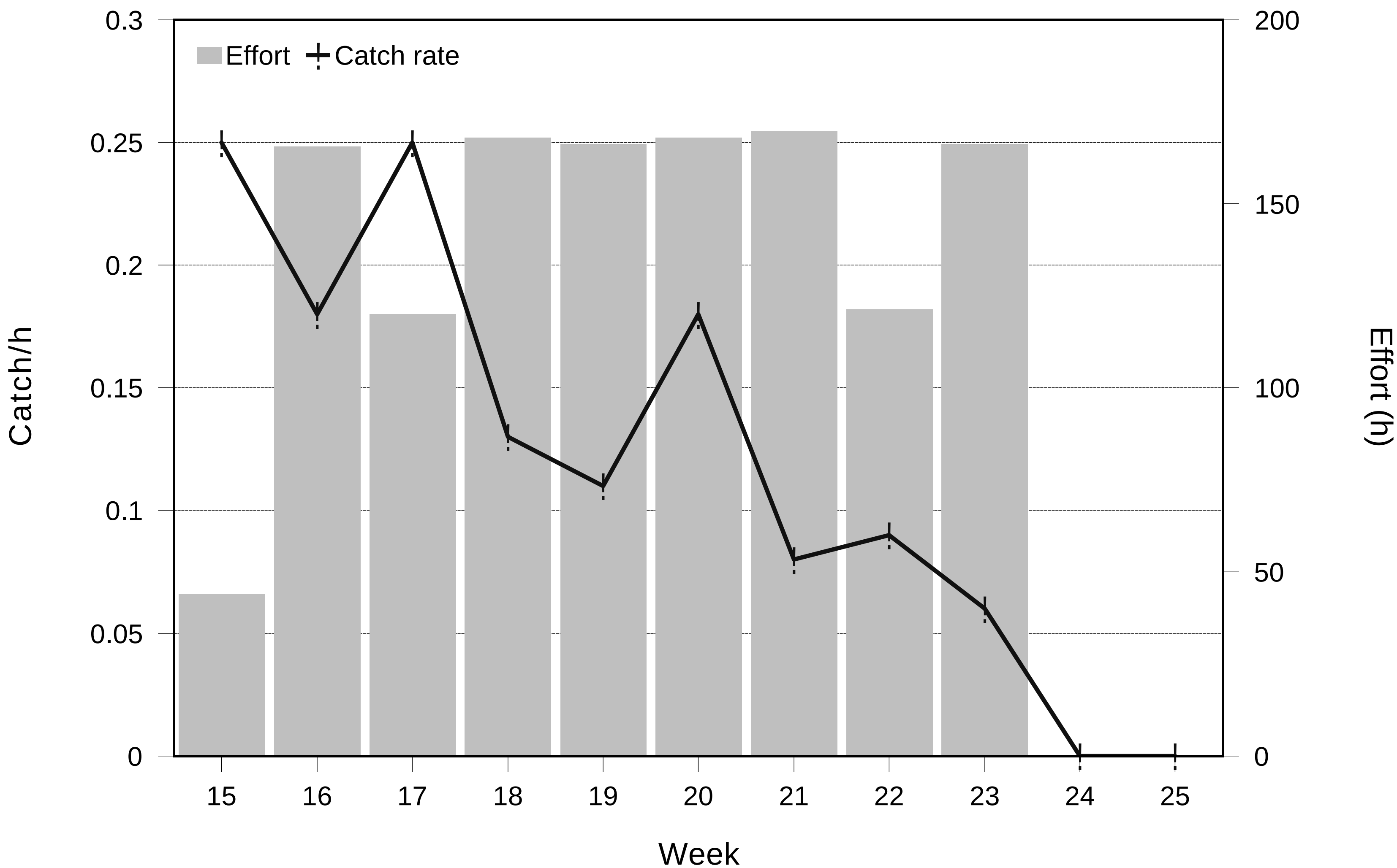


Figure 8. Weekly catch rate (n/h) of chinook salmon and hours fished by rotary screw trap on the Cosumnes River, April 1999 - June 1999.

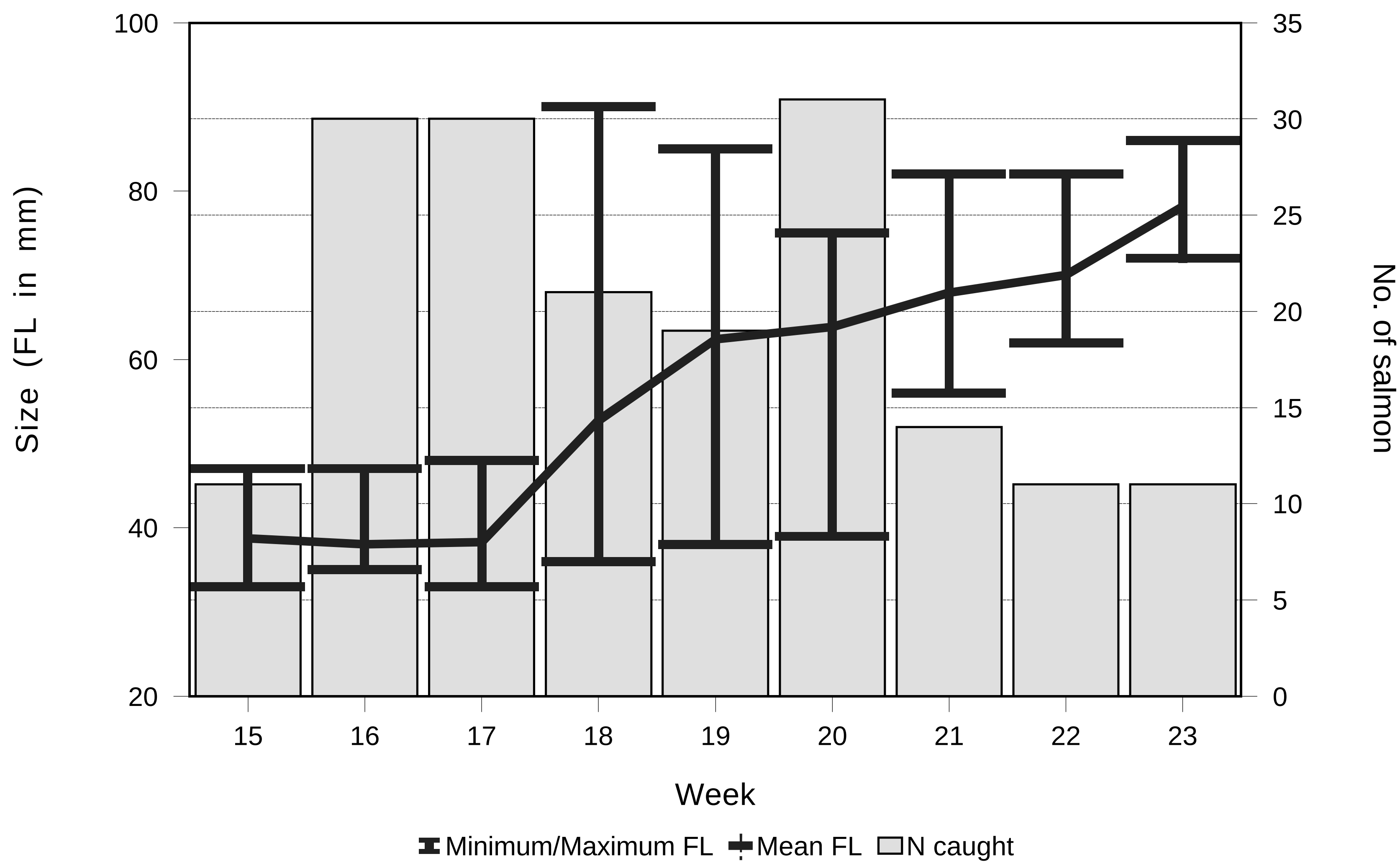


Figure 9. Weekly catch and size statistics of chinook salmon caught by rotary screw trap on the Cosumnes River, April 1999 - June1999.

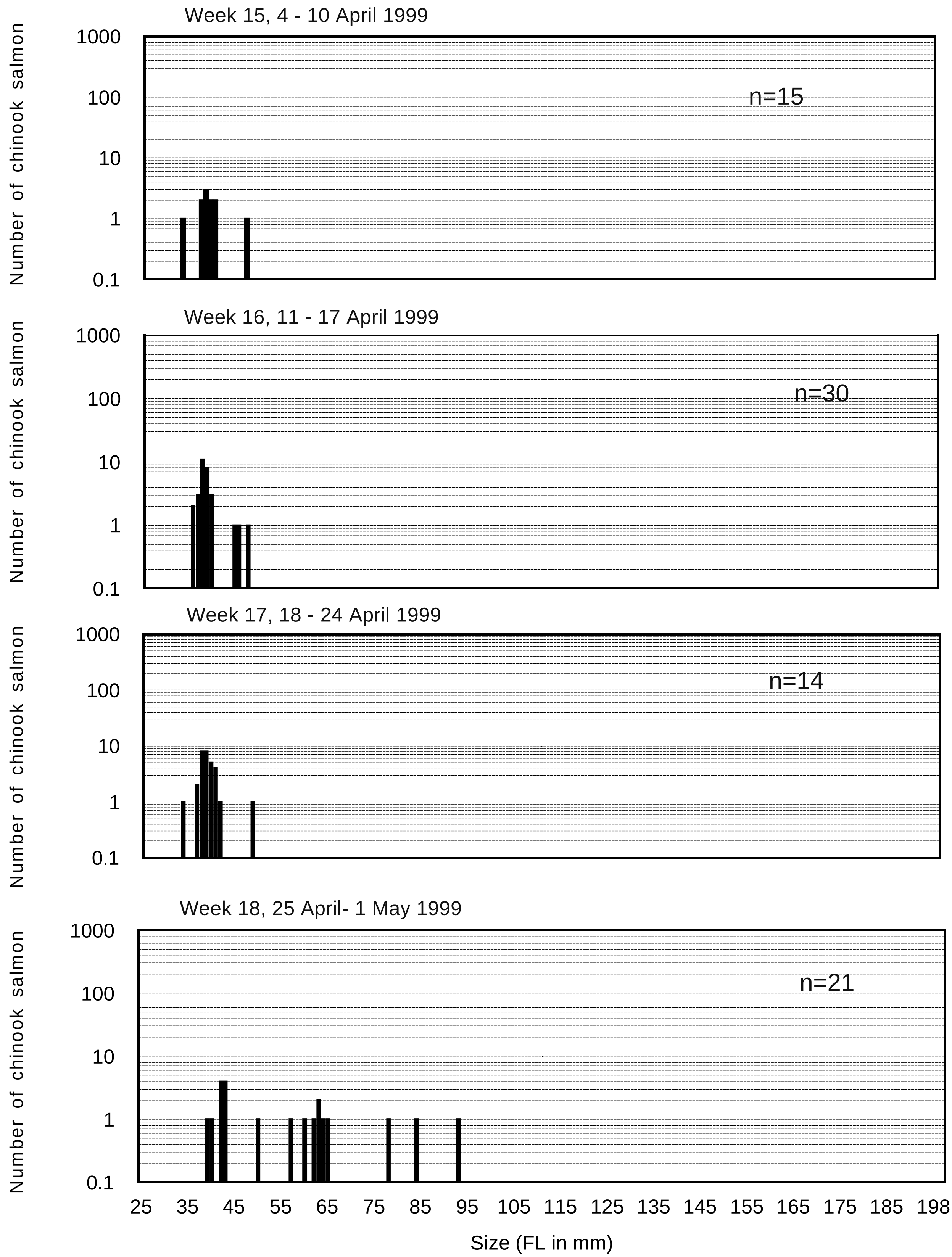


Fig 10. Size distribution of chinook salmon caught by rotary screw trap in the Cosumnes River, 4 April - 1 May 1999.

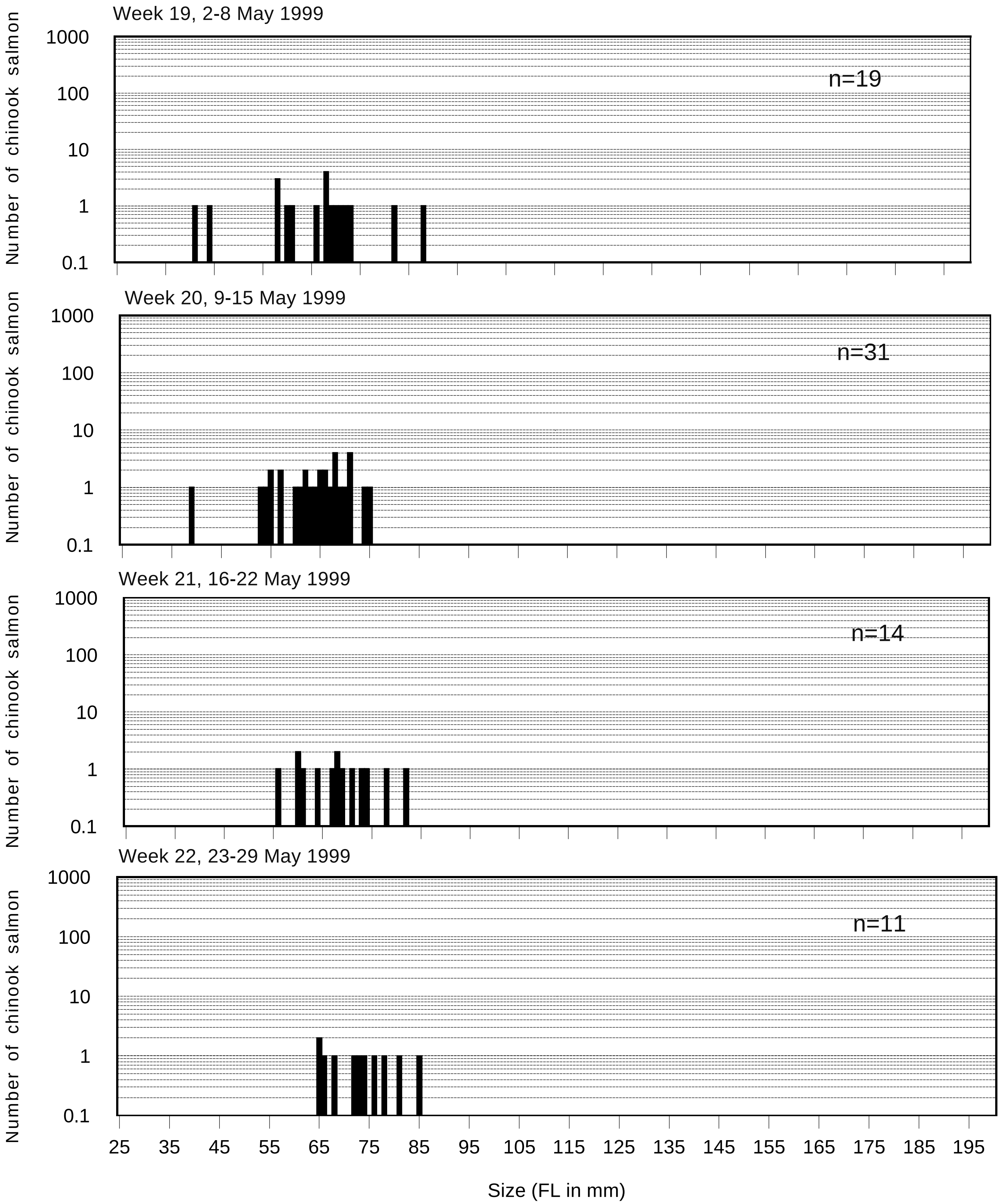


Figure 11. Size distribution of chinook salmon collected by rotary screw trap in the Cosumnes River, 2 May - 29 May 1999.

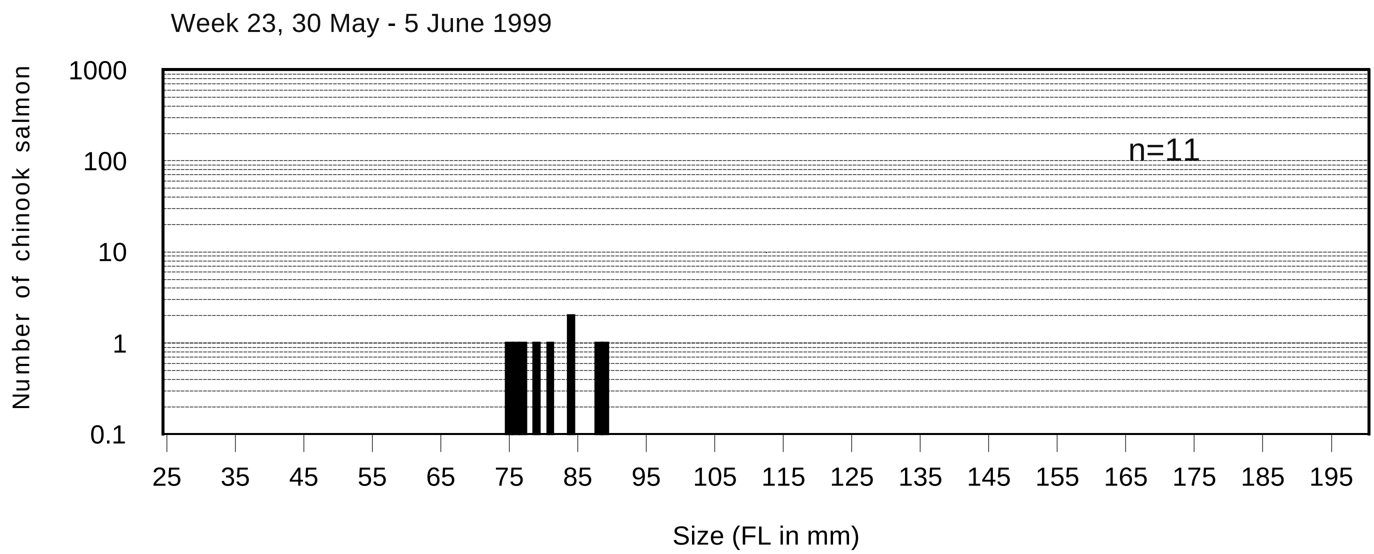


Figure 12. Size distribution of chinook salmon collected by rotary screw trap in the Cosumnes River, 30 May - 5 June 1999.

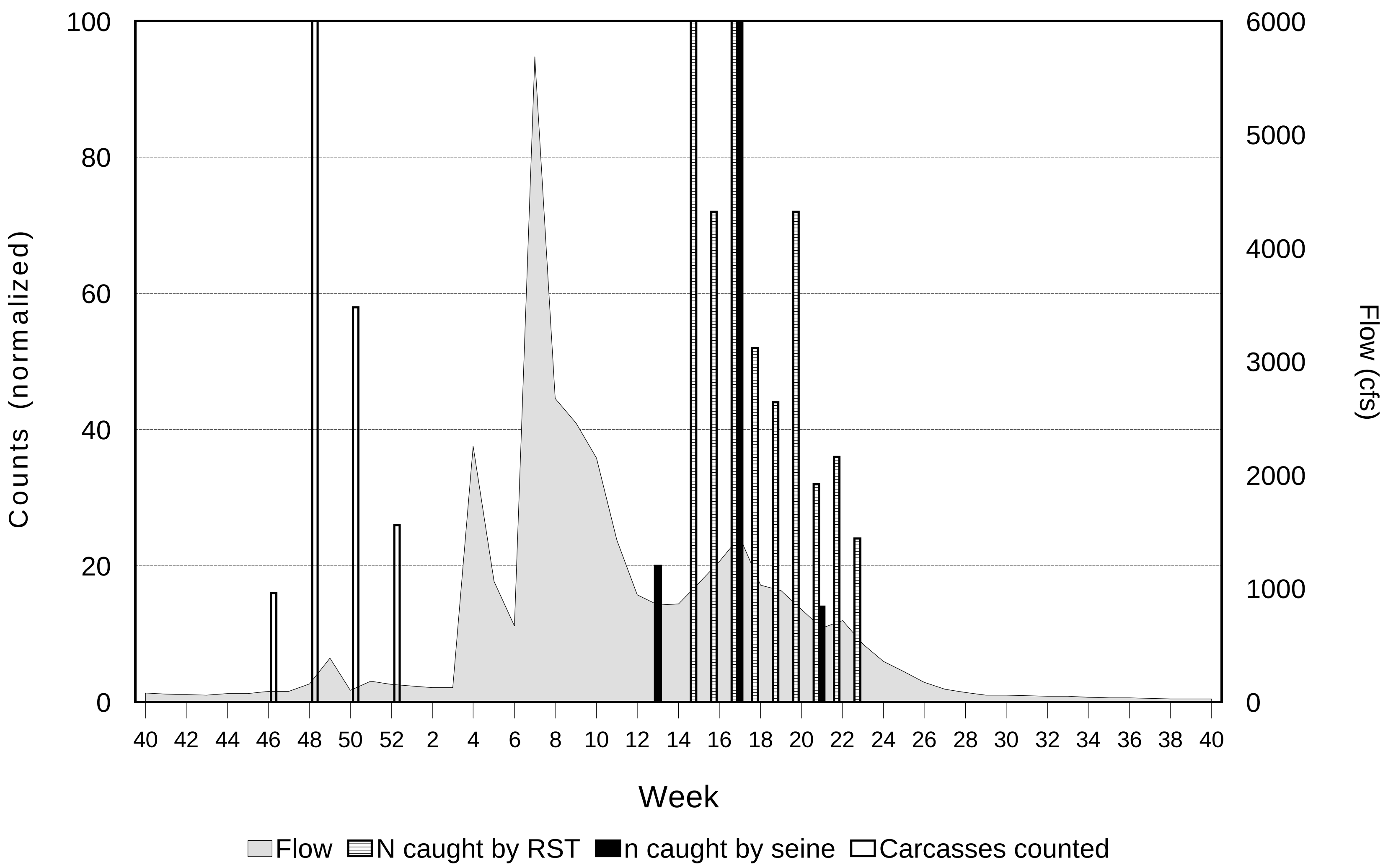


Figure 13. Temporal distribution of carcass counts, seine and rotary screw trap catches relative to flow on the Cosumnes River, October 1998 - September 1999.

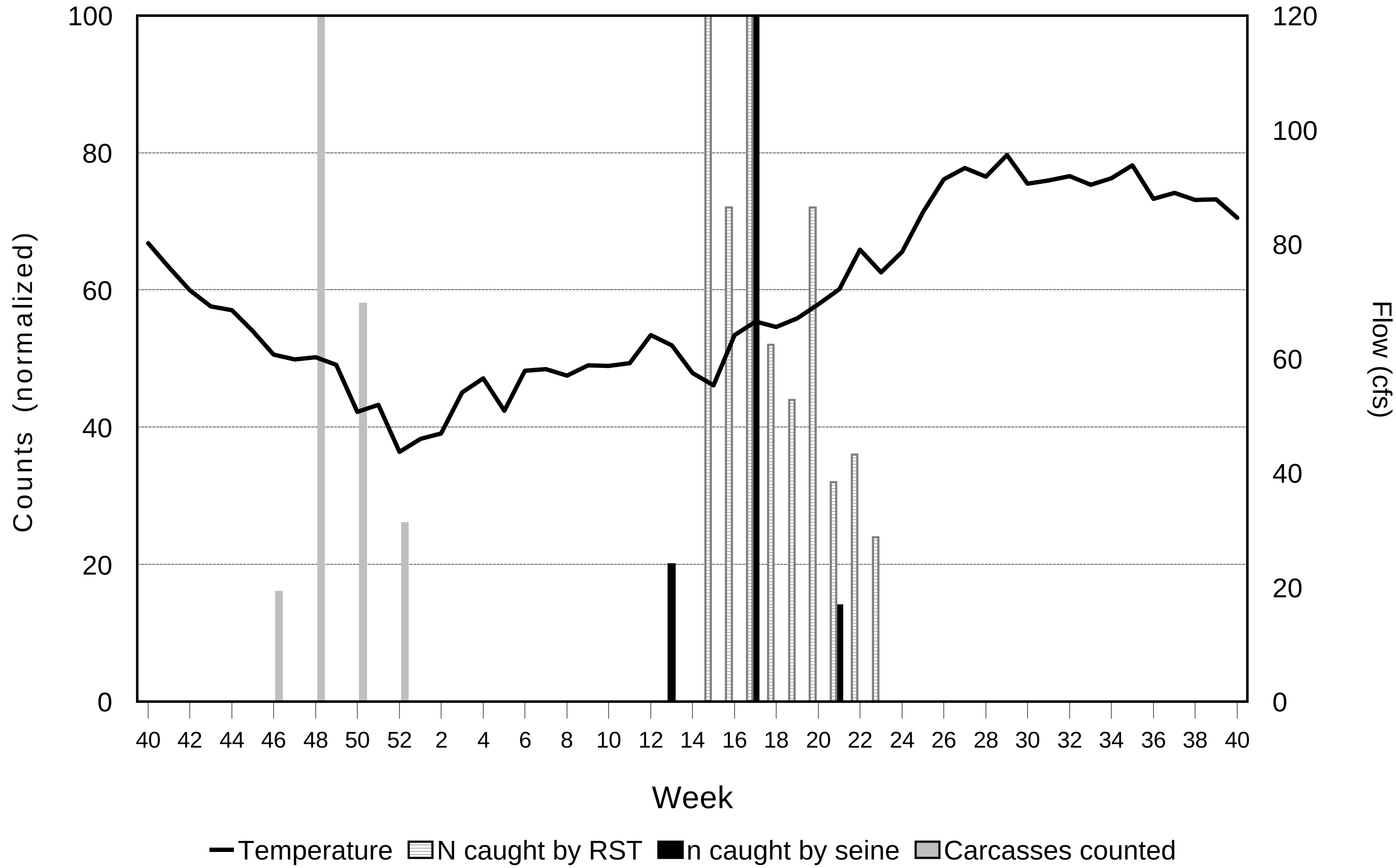


Figure 14. Temporal distribution of carcass counts, seine and rotary screw trap catches relative to temperature on the Cosumnes River, October 1998 - September 1999.

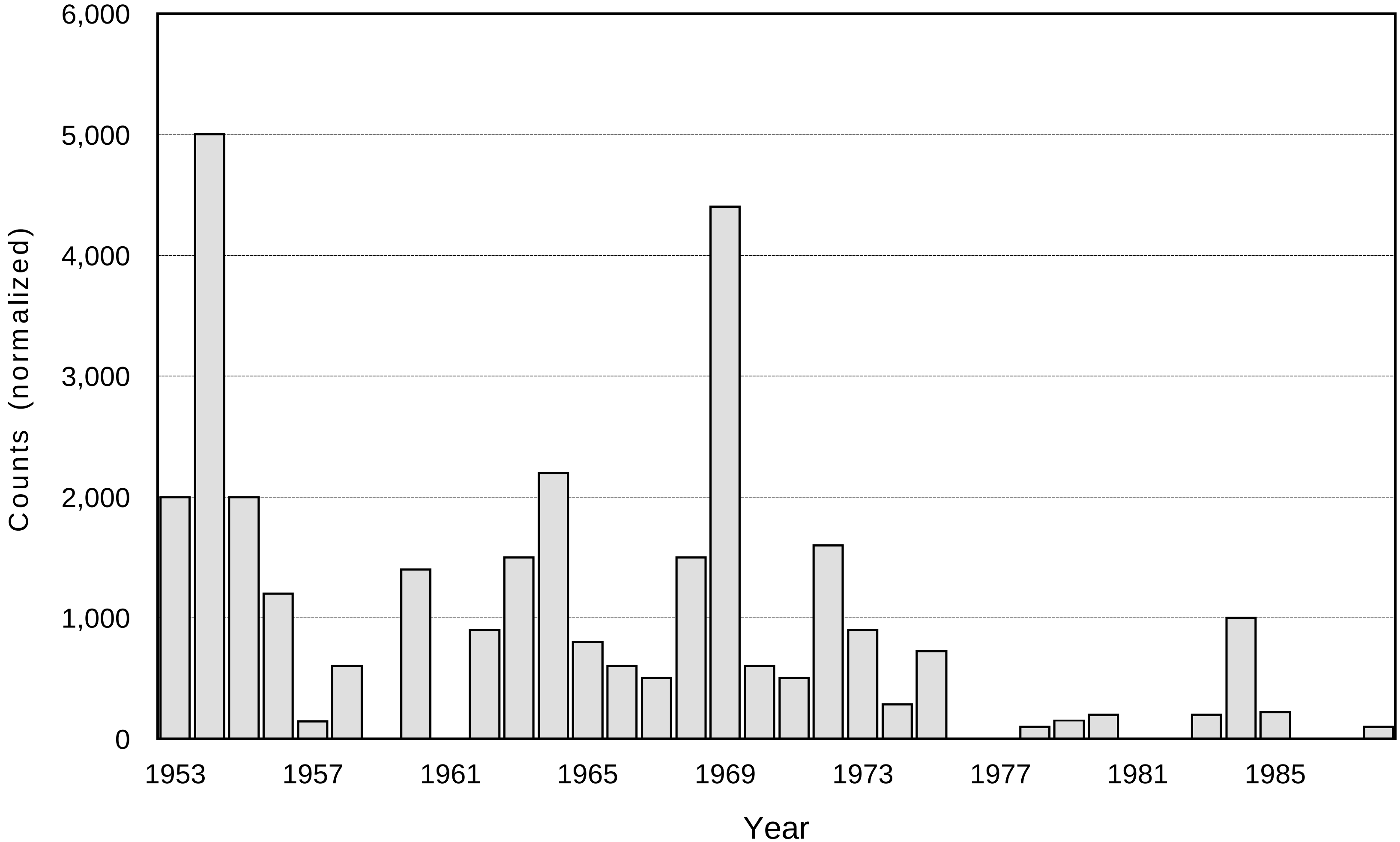


Figure 15. Estimated annual chinook salmon escapement to the Cosumnes River, 1953–1988. (No estimates were made during 1959, 1961, 1976, 1977, 1981, 1982, and 1986).